Everything for the Glasshouse

H. L. Dixon Company
Pittsburg, Pa.


THE GETTY CENTER LIBRARY
Why ask for the moon
when we have the stars?
AS

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Introductory

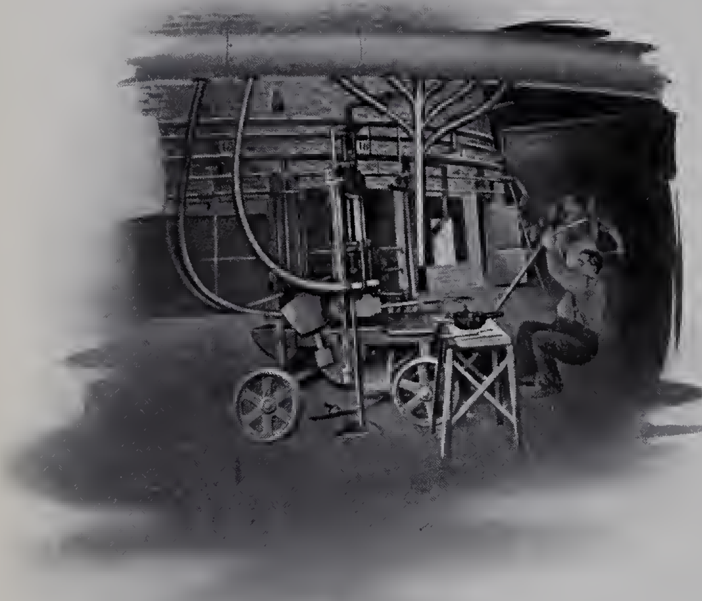
A LONG experience in designing and constructing furnaces and appliances for the manufacture of glass, has led to the development of many improvements which have resulted in a great saving of fuel and a reduction of operating expense, as well as a very large increase in production.

The adoption of the continuous tank furnace, first for the manufacture of green and amber bottles, to be later followed in quick succession for the making of window glass, flint bottles and tableware, has probably been the most important innovation, as well as one that has affected the condition of the glass business more than any other.

The adaptation of the well-known Siemens regenerative system to rectangular, circular and elliptical pot furnaces, has not only reduced the fuel consumption, but has increased the melting capacity of such furnaces, improved the quality of the glass and reduced the danger of breaking pots to the minimum.

The introduction and perfection of the continuous lehr for annealing plate glass, has upset the accepted theories of the experienced manufacturers of polished plate glass. The delivery of plates through a lehr within three or four hours after the glass lay in the pot in a molten state, instead of leaving them in a kiln from two to three days, was, only a very short time ago, considered an impossibility.

Blowing and Moulding Lantern Globes (Flint Glass Factory)



Pressing a Bowl
(Flint Glass Factory)

Improvement in the quality and preparation of furnace material has kept pace with the demand for better and more refractory material, due to the increase of furnace production and the employment of a much higher range of temperatures. The latest development is that almost indestructible material known as Corundite, destined to come into general use in the near future.

The introduction and improvement of machinery in the manufacture of all lines of glassware, have made rapid strides in the last few years and have met with such pronounced success as to shatter many more hobbies of the conservatives.

In the rapid march of improvement, we have ever been in the front rank; many of the improved appliances now in use having originated with us. What we have to offer in this line is based upon a certain knowledge, acquired by actual experience, of the results that can be obtained.

Drawing Pot of Metal from Furnace
for Purpose of Casting
(Plate Glass Factory)

Important

WE are prepared to contract for the construction and equipment of glass manufacturing plants complete, to make the glass and start them in successful operation. We have complete data as to the cost of manufacture, both with producer gas and with natural gas, and we employ the most competent and experienced men in designing, constructing and operating glass plants of every description. We have also the recipes or formulas for all kinds of glass, in opal, crystal or colors, both for tank and pot furnaces, all for use of our customers and patrons.

Casting a Pot of Metal on a Table
(Plate Glass Factory)

The Works at Rosslyn Station, Carnegie, Pa.

Manufacturing and Shipping Facilities

OUR Foundry and Machine Shop is located at Rosslyn Station, Carnegie, Pa., on line of P. C. C. & St. L. Ry. and the P. C. & Y. R. R., which gives us connection with the Erie R. R., L. S. & M. S. and B. & O. Railway Systems, as well as the Pennsylvania.

The Machine Shop is equipped with modern machinery for the manufacture of glasshouse tools and implements, as well as a general line of machine work, and the fabrication of structural material and other ironwork used in the construction of furnaces, lehrs, gloryholes, etc., etc.

With our Foundry supplied with modern facilities, in connection with the Machine Shop, we are prepared to execute promptly all orders for machines, tools, moulds, implements, furnaces and lehrs.

Fig. 1
Regenerative Pot Furnace

Regenerative Flint Glass Pot Furnaces

THESE furnaces (Fig. 1) are built either in elliptical or circular form and for 14 to 20 pots, with no vacant pot openings, the ports being entirely within the circle of pots; for less than 14 pots it is necessary to either omit a pot on each side or to use pots in these places of a reduced size.

The elliptical furnace is not as good as the circular furnace for several reasons; besides the greater inconvenience of working around them, the pots do not melt uniformly, the middle pots melting three or four hours faster than the end pots; the strength, permanency and durability of a circular furnace makes that form of construction much more desirable; the distribution of the heat is uniform and there is no variation in the melting time, thus enabling the glassmaker to more accurately adjust the coloring and to arrange for working the shops to advantage. The fuel saving is from 50 to 60 per cent, either with producer gas or natural gas.

This furnace is built for either natural gas or producer gas and can easily be changed from one to the other without any alterations or stopping operation.

Old style furnaces can readily be remodeled to this plan, and the saving of fuel and pots will soon repay the cost of the change.

Our patented regenerative furnace with the regenerators at one side of the furnace, under the factory floor in the basement, and having the gas and air ports entirely within the circle of pots, is easily adapted to old style furnaces, avoiding much of the expense of remodeling.

We have twenty-three furnaces of this type in operation, and they recommend themselves, having entirely superseded the Nicholson and Gill Furnaces, the best types of former days.

We are prepared, however, to build or repair any style of furnace desired, either "Gill," "Nicholson," "Deep Eye," "Murphy" or old style "Side Teasers," or the simple form of eye for use of natural gas.

Flint Glass Lehrs

The proper construction and regulation of the lehrs used for annealing glassware is a very important feature of the glass business. The ordinary type of pan lehr is constructed for use of coke, oil and natural gas, and by use of our **Patented Air Mixer Burners** we have successfully applied producer gas for this purpose, both with fires under the pans and with the burners above the pans, the latter is preferable, because the sulphur stains due to under firing is entirely avoided and the ware is clean. Lehrs fired in this way are in use for annealing heavy bottles and all lines of glassware. We build pan lehrs in single and double deck, the latter being useful where it is necessary to economize room.

To dispense with the inconvenience of using a series of pans, we have perfected a lehr with an endless carrier that may be propelled by hand or by electric motor or other power, either moving continuously or intermittently.

By our method of applying producer gas in lehrs, with burners above the pans, the combustion can be so accurately controlled as to eliminate all smoke and soot from the lehr, resulting in clean ware free from sulphur stain.

Fig. 2. Lehr Fronts

Gloryholes

We construct gloryholes (Fig. 3) of the most approved type for finishing all kinds of pressed ware, blown ware, lamp chimneys, bottles, etc., and have successfully applied producer gas for this purpose. We manufacture and construct these in the best manner and make a specialty of portable gloryholes for use of oil or gas.

Pot-Arches and Mould Ovens

To insure the successful use of pots, it is necessary to have pot-arches that will heat them properly and uniformly. We build them (Fig. 4) with this purpose in view, for natural gas, producer gas or direct firing.

The old method of heating moulds by filling them with glass is not only wasteful but injurious to the mould. A mould oven with a carriage on a track is a great convenience, and facilitates the work by having the moulds ready and uniformly heated.

Fig. 3. Gloryhole

Decorating Ovens and Lehrs

We manufacture and construct decorating muffle kilns either with tile lining or with boiler plate lining; the latter is convenient for quick firing but is not as durable as the tile lined kiln. Our kilns are securely bound and have substantial clay or brick lined doors. We also furnish the ware-racks when required.

Continuous lehrs for decorating are extensively used for all kinds of ware; the best class of lamps, shades and globes are burnt in them and they have a much greater capacity than kilns. We build them with tile lined muffles, or for the cheaper grades of ware with open fires for natural gas. They are effective, convenient and speedy.

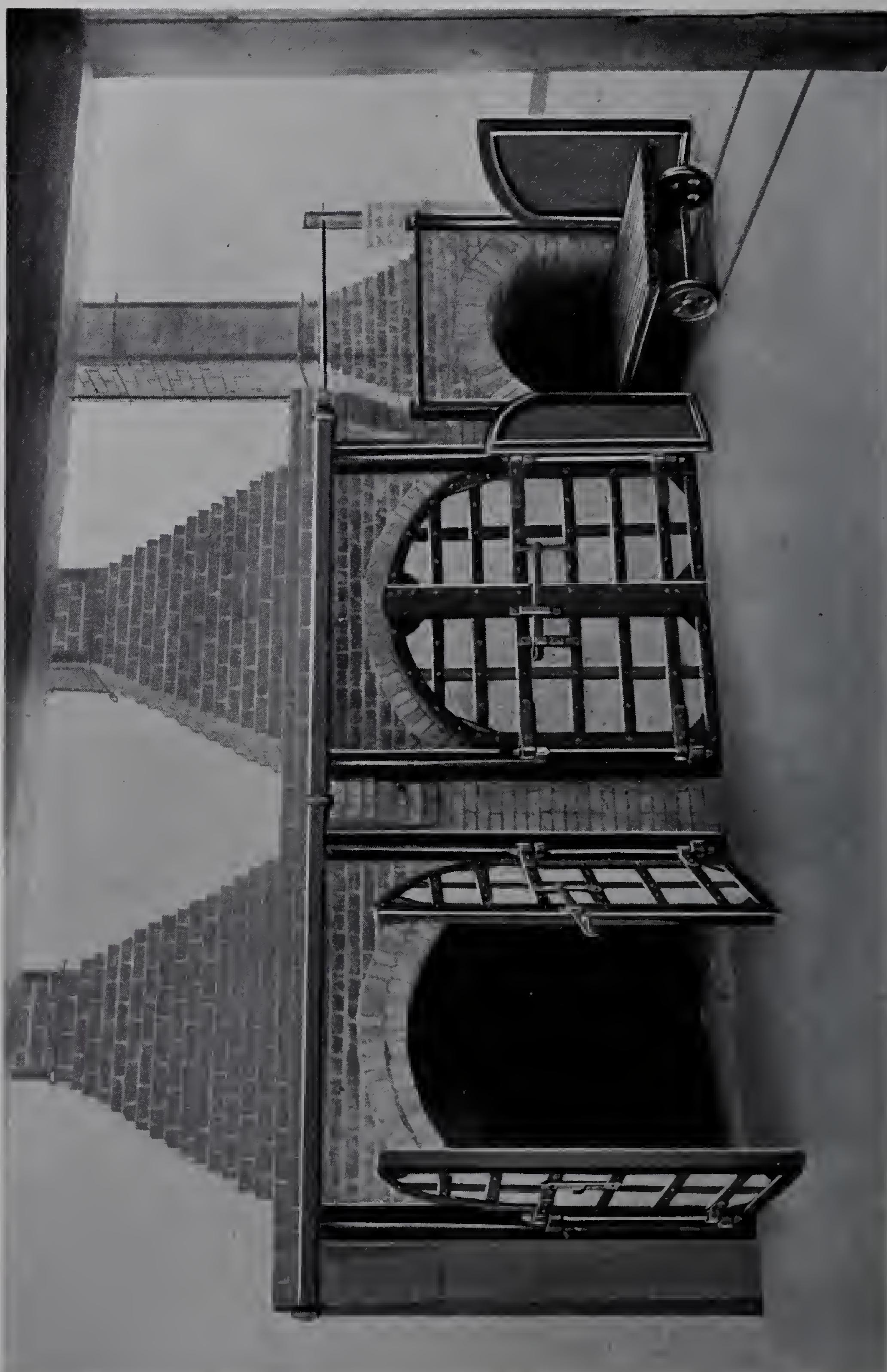


Fig. 4
Pot-Arches and Mould Oven

Stained Glass Kilns

We make kilns for burning stained glassware of boiler plate, either in circular or elliptical form, or with straight sides and bottom and arched top. The ware pans may be supported upon cast iron stands or by angles riveted to the sides of the muffle. They are set up singly or in batteries and the ware pans and stands are furnished complete if desired. They are particularly useful for rapid firing, as they can be heated and cooled quickly.

Opal Glass Tanks

Daily melting tank furnaces of two to ten tons capacity are in general use for opal, flint and other kinds of glass, and while they are useful in many instances for special purposes, they are not intended for a large production and are not as economical as continuous tanks. To insure good results and lowest cost for fuel, they should be constructed with regenerators, although most of them are operated by direct firing, but with some waste of fuel.

Continuous Melting Tank Furnaces for Opal Glass are now being used and a very good quality of glass is made in them. The cost of operating is materially reduced, the production increased and the life of the furnace is prolonged; three very important features worthy of consideration. We are prepared to build them.

Continuous Melting Tank Furnaces of our design and construction have been almost universally adopted for the manufacture of green, amber and flint bottles, as well as the cheaper grades of tableware, tumblers, lamp chimneys, bar goods, etc. They are also extensively used for the manufacture of wire glass, skylight and prism glass, either in crystal or light green.

The introduction of this type of furnace has been responsible for an enormous increase in the production of this class of glassware, and, in the hands of the skilled glassmaker, produces glass that is scarcely distinguishable from pot glass.

We construct these furnaces with a view of obtaining the largest production of best quality with the lowest expenditure of fuel, and have attained results which have never been equaled.

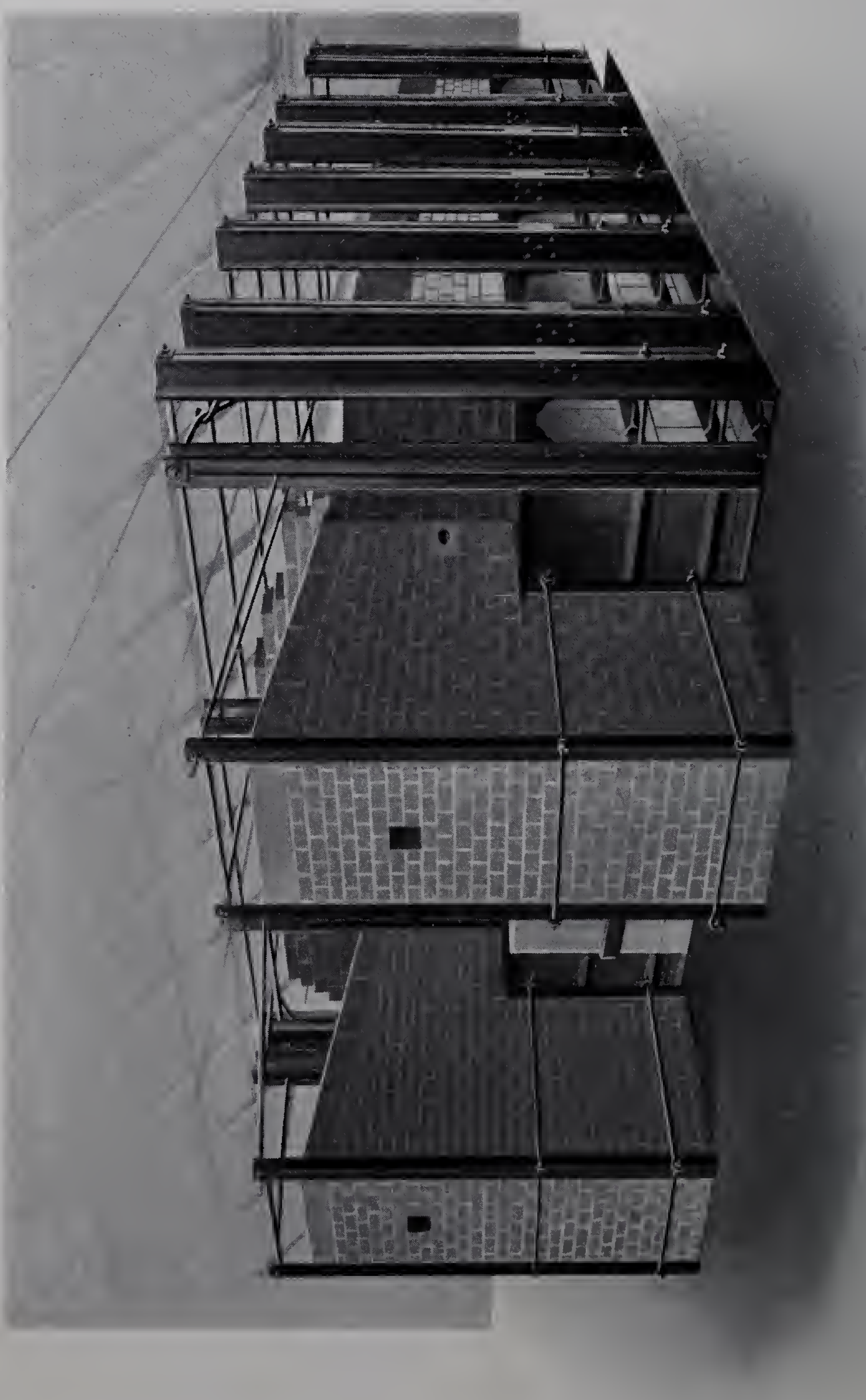
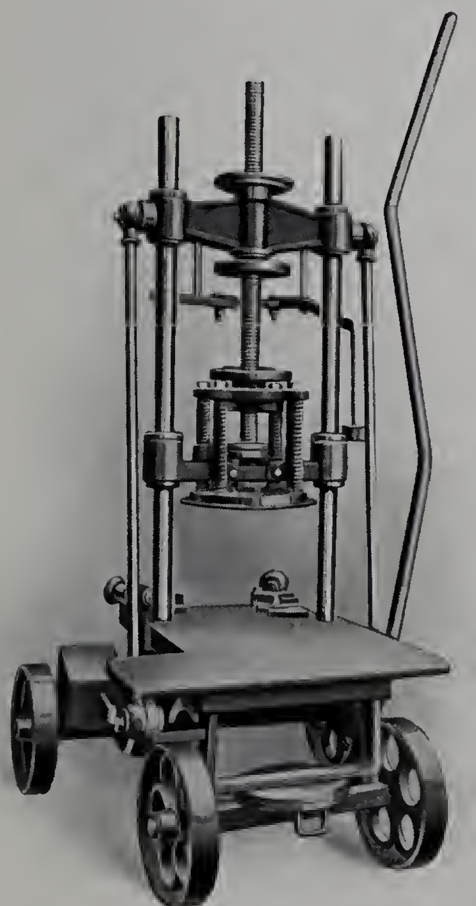


Fig. 5
End Port Tank Furnace

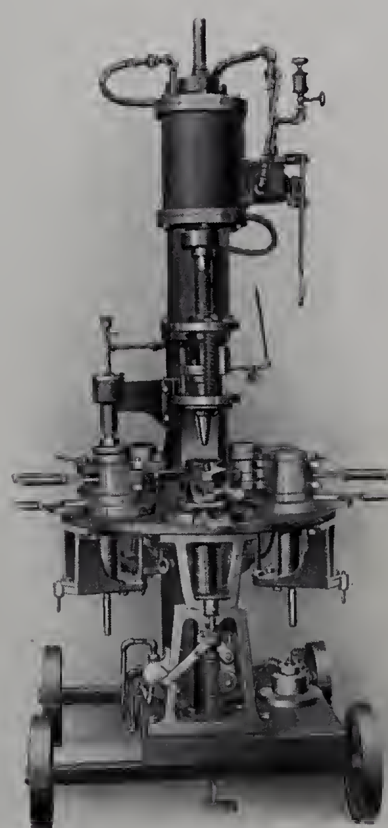
Pictorial Sketch of

Modern Pressing and Blowing Machinery



The Original
WASHINGTON BECK
SIDE LEVER PRESS
is still the best
and most durable

Fig. 6
A Standard Press



COX-WINDER SEMI-AUTOMATIC
PRESSING AND BLOWING MACHINE

Adaptable for large and
small bottles, fruit jars,
milk bottles, etc.

Fig. 7

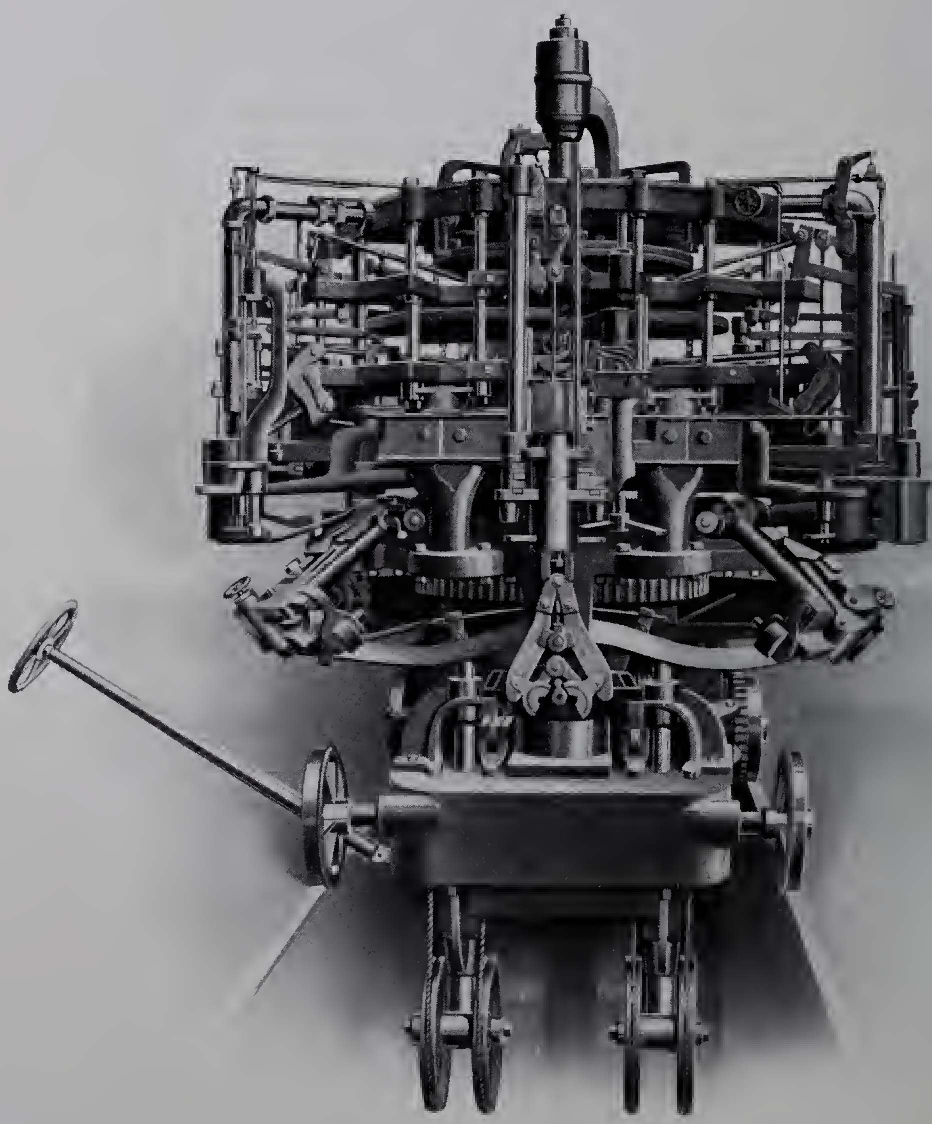


Fig. 8

Owens Automatic Gathering and Blowing Machine
For the manufacture of all lines of hollow glassware

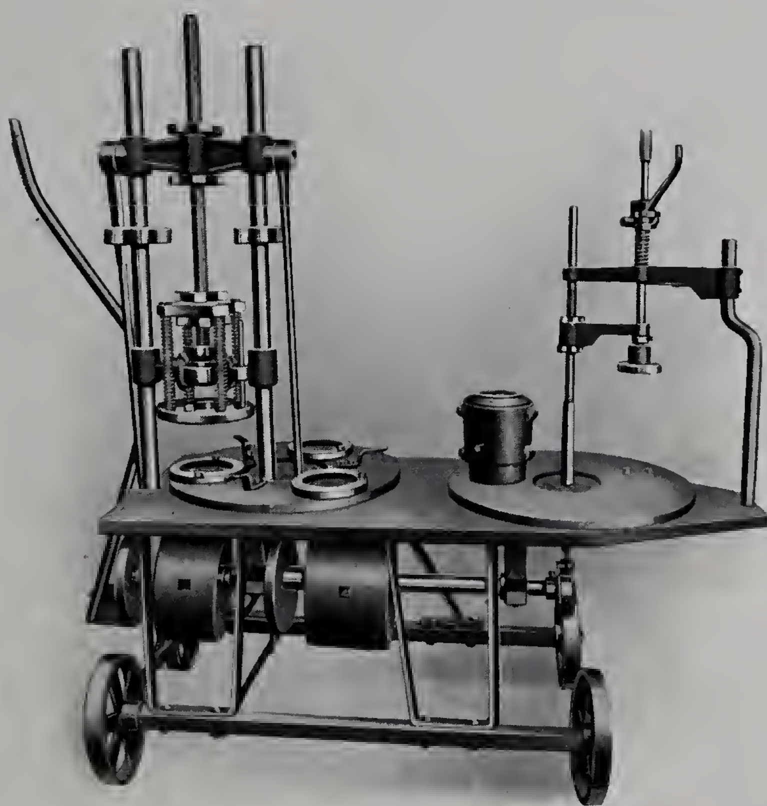


Fig. 9. Teeple-Johnson (Large)

THE TEEPLE-JOHNSON PRESSING AND BLOWING MACHINES
Is very simple in construction and operation
It is used extensively for milk jars and wide mouth ware

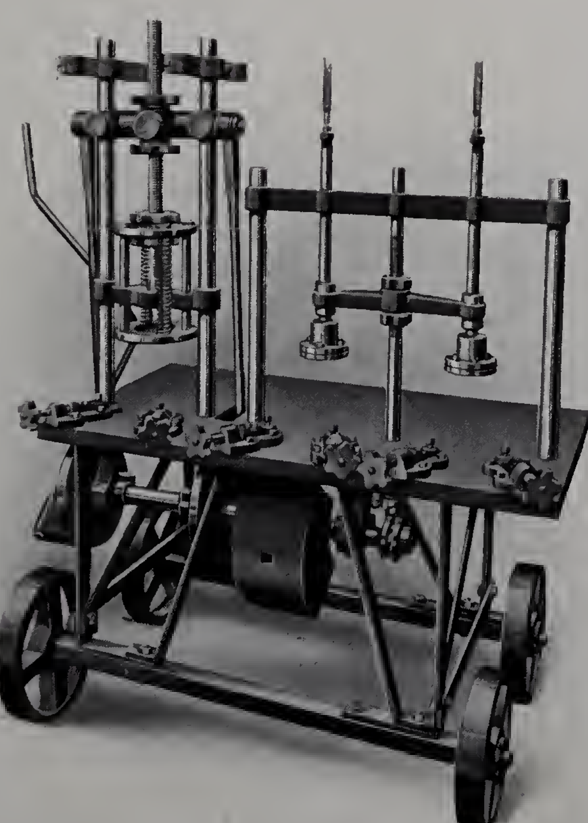
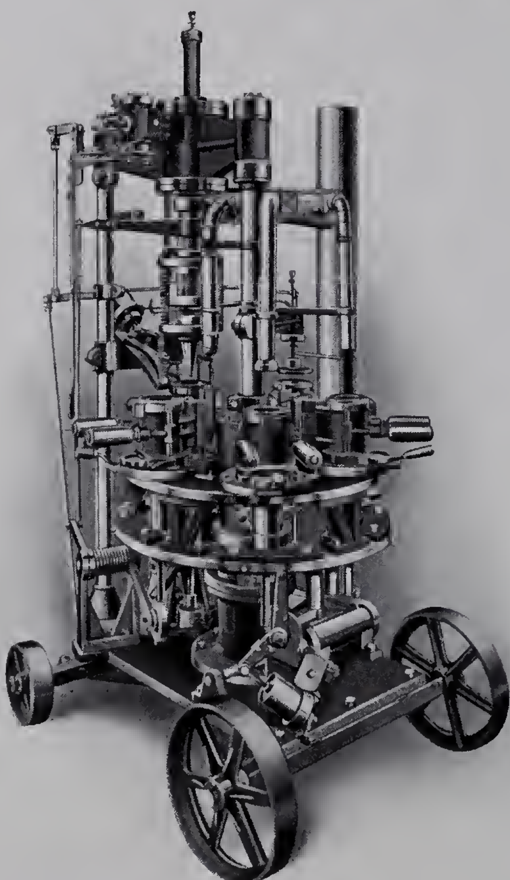


Fig. 10. Teeple-Johnson (Small)



MILLER SEMI-AUTOMATIC
PRESSING AND BLOWING MACHINE
Suitable for full line of jars and wide mouth bottles

Fig. 11

JOHNSON-FRY SEMI-AUTOMATIC
PRESSING AND BLOWING MACHINE
Suitable for jars, milk bottles, lantern globes and a full line of semi-wide mouth bottles

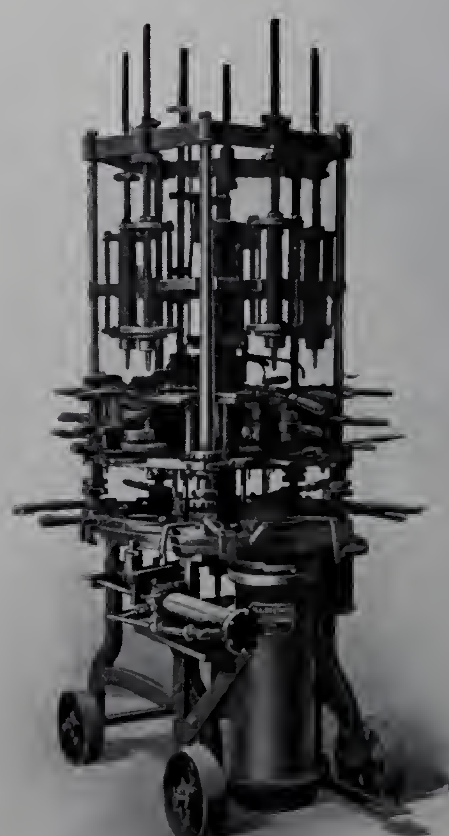


Fig. 12

THE BLUE
IMPROVED SEMI-AUTOMATIC
PRESSING AND BLOWING MACHINE

Used extensively for fruit jars and all wide mouth bottles

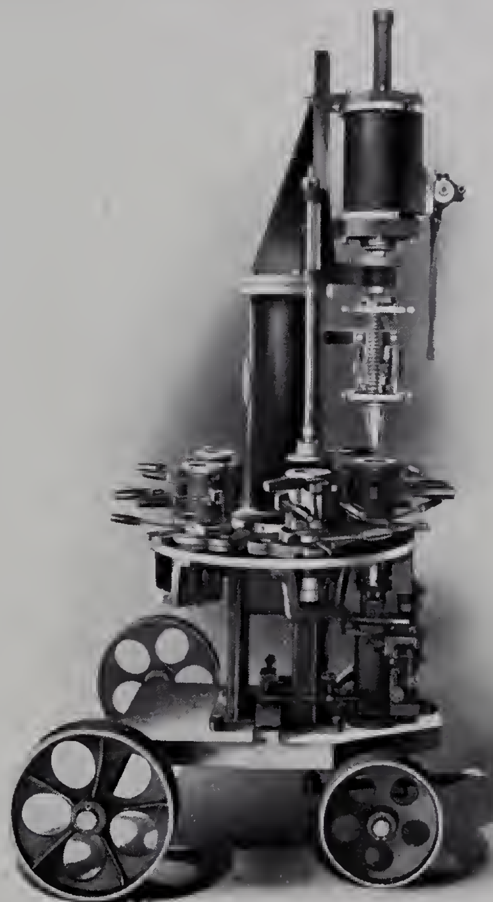


Fig. 13

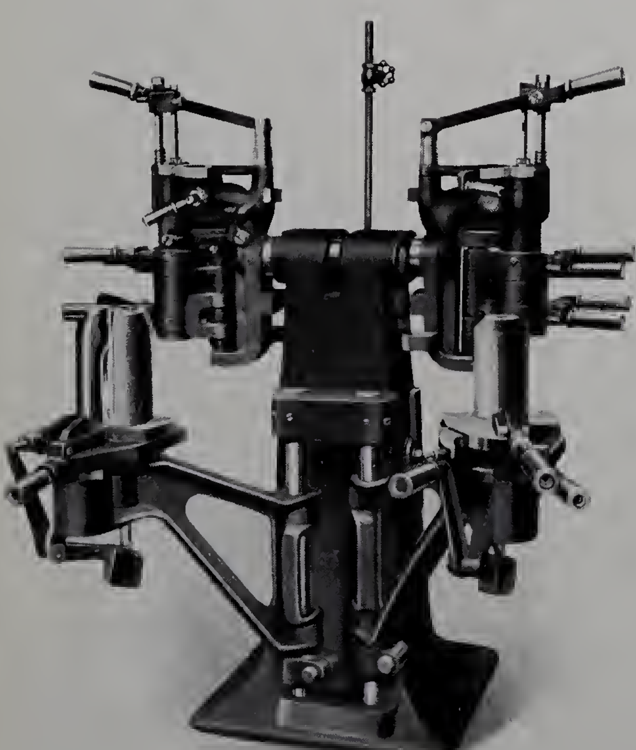


Fig. 14

THE PIERPONT-DEMMING
BLOWING MACHINE

In use for manufacture of beers, sodas and other narrow neck bottles

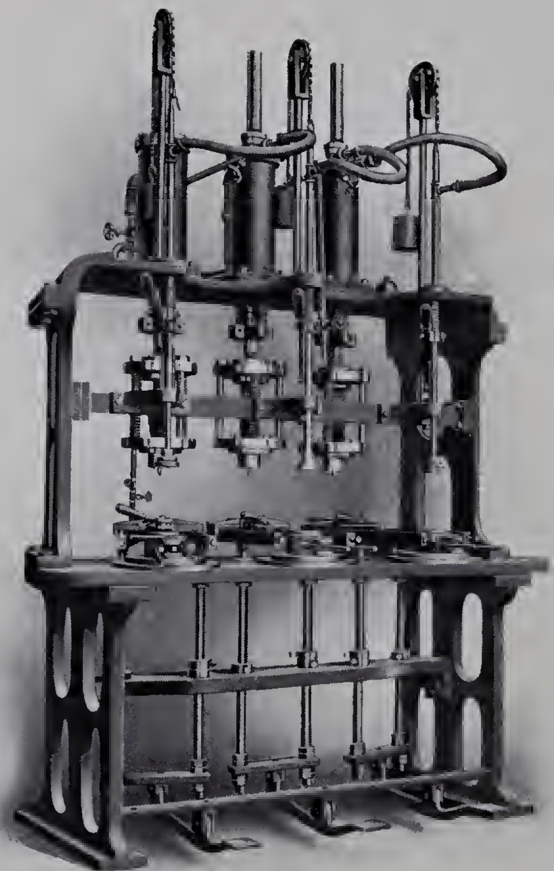


Fig. 15

THE PANCOAST MULTIPLE PRESSING AND BLOWING MACHINE

Particularly noted for large production of small semi-wide mouth bottles

THE WINDER SEMI-AUTOMATIC PRESSING AND BLOWING MACHINE

For narrow neck bottles

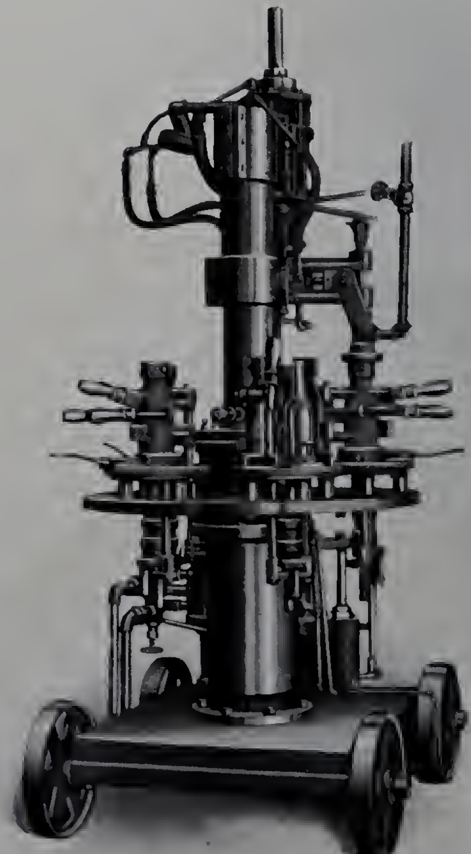


Fig. 16

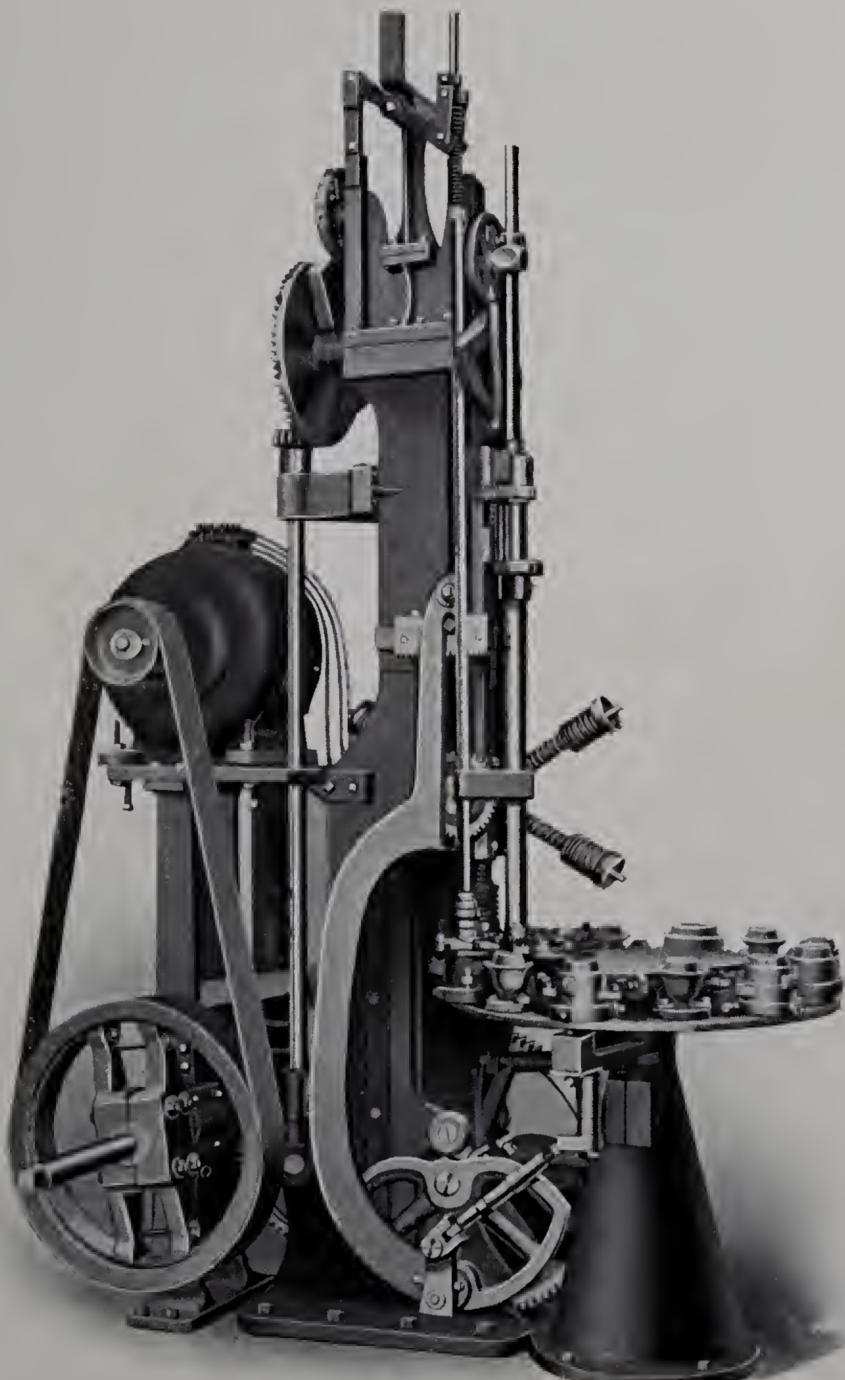


Fig. 17

The O'Neil-Gordon Pressing and Blowing Machine

Used for milk jars and other wide mouth ware

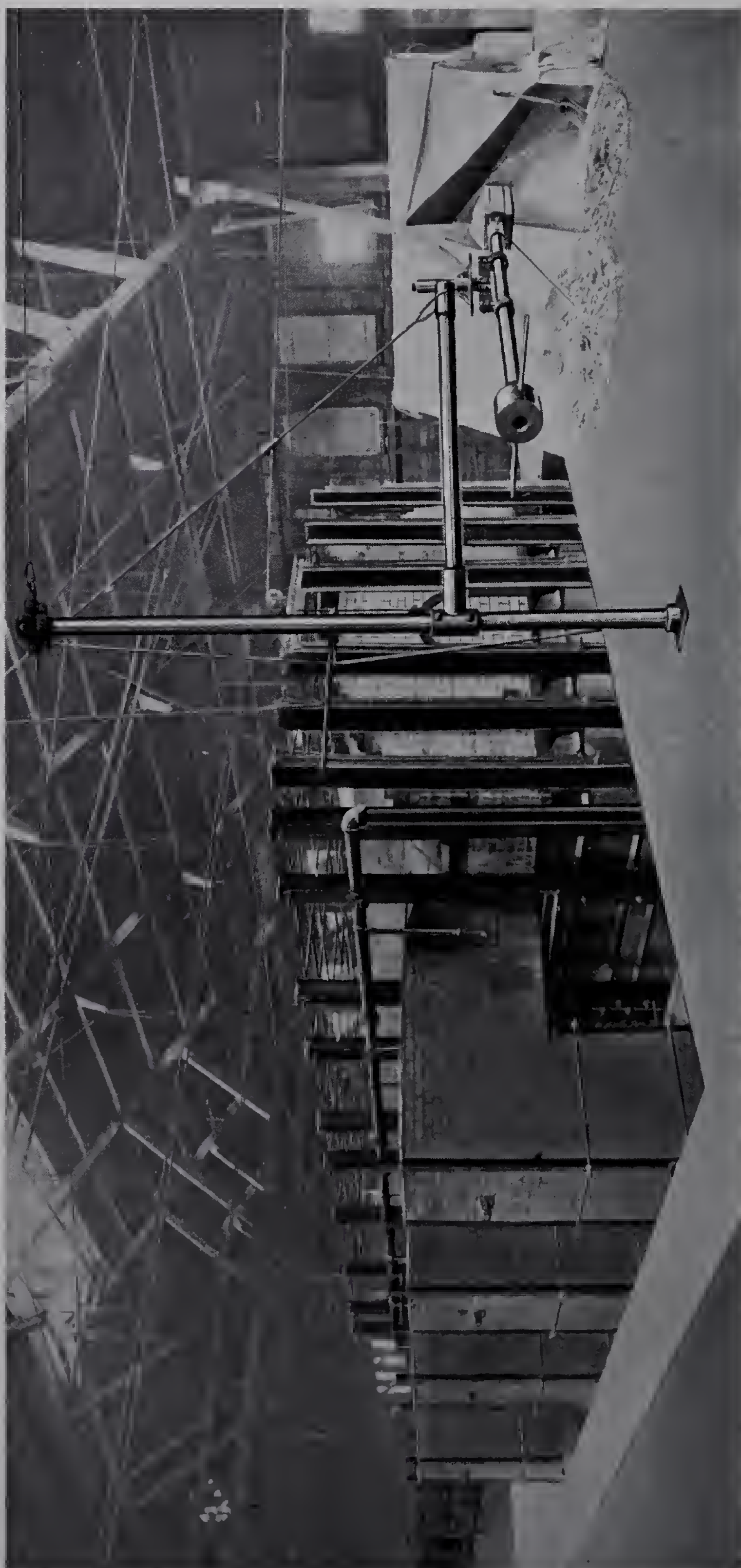


Fig. 18
Side Port Tank Furnace with Crane Filling Shovel

Window Glass Tank Furnaces

The continuous melting tank furnace (Fig. 18) has entirely superseded the pot furnace of former days for the manufacture of window glass. Whether operated with natural gas or producer gas, there is a great improvement in the quality of the glass produced as well as a considerable saving of fuel and labor, as compared with the best type of pot furnaces.

We construct them of any capacity from 12 blowers up to 60, and it is generally conceded that tanks of our construction are the most substantial and durable, and that they embody all of the necessary conveniences to facilitate the resetting of blocks and making repairs.

Our patented blow-over tanks are of the best design and construction for the perfect regulation of the temperatures for melting, blowing and gathering. The record we have made in production, quality and economy of fuel stands pre-eminent.

Machinery is rapidly displacing hand labor for the manufacture of window glass. The Lubbers cylinder machine was first introduced and is now extensively used. Other cylinder machines, such as the Slingluff, Milliron, Pease and Bolin are being perfected and installed in rapid succession, for drawing directly from the tank. The latest achievement in the manufacture of sheet glass is the perfection of the Colburn Sheet Glass Drawing and Annealing Machine (Figs. 19 and 20) which delivers a continuous sheet of glass of any desired thickness from the tank furnace to the discharge end of the lehr, dispensing with blowing and flattening.

It is evident that the arrangement of the tank furnaces for the proper regulation of the temperatures in the drawing chambers, as well as for the melting and refining of the glass, is of the greatest importance, and is essential to the successful operation of the machines. An intimate knowledge of the requirements of both cylinder and sheet drawing machines enables us to make the alterations necessary to adapt old furnaces to the use of machines, as well as to properly construct new ones for that purpose.

The convenience of the arrangement to facilitate the handling of the cylinders or sheets without liability of breakage and with the minimum expenditure of labor, is of the utmost importance and requires careful attention on the part of the engineer in preparing the specifications for such alterations and equipment.

Fig. 19. (Drawing End)
THE COLBURN WINDOW GLASS DRAWING MACHINE AND ANNEALING LEHR
(Built by H. L. Dixon Co.)

Fig. 20. (Delivering End)
Melting Tank and Colburn Window Glass Drawing Machine and Annealing Lehr
(Built by H. L. Dixon Co.)

Flattening Ovens and Lehrs

FIRST PROCESS: FORMING THE CAP
(Window Glass Factory)

The four-stone flattening oven and lehr introduced in this country by Cleon Tondeur in 1882, is the only style of oven and lehr that is built today. Its advantages were quickly recognized and its adoption by all of the window glass manufacturers was rapid and universal.

We have made many improvements in its design and construction and use lehr machinery mounted on anti-friction bearings which has many advantages over the old style of machinery. The sizes are as follows: wheels 14′-9″ diameter with lehr 44′-0″ long, 6′-6″ wide inside; wheels 16′-0″ diameter with lehr 48′-0″ long, 7′-6″ wide inside; wheels 18′-0″ diameter with lehr 52′-0″ long, 8′-4″ wide inside.

These lehrs and ovens are constructed in a most substantial manner, and with a due regard for proper firing and the perfect regulation of the temperature.

Blowing Furnaces

These furnaces we construct for blowing on both sides or with one blind side, either with straight or curved sides; the latter providing plenty of room for foot-benches and for full length cranes. The pipe heating and blowing furnaces are so constructed that they drain to a tap hole.

BLOWING THE CYLINDERS
(Window Glass Factory)

Floater Kilns

We build these kilns of various sizes to suit the length of the floaters. They are suitable for burning rings, blocks and flattening stones as well

CRACKING OPEN THE CYLINDERS
(Window Glass Factory)

as floaters. The doors are made of heavy steel angles, well braced and filled with fire clay, and are hinged on the front buckstays. The brick chimney is bound with angles and provided with damper and frame at the top for regulating the draught.

Plate Glass Melting Furnaces

These furnaces are constructed for 20 to 24 pots, of the Siemens regenerative type for either natural or producer gas, with the ports in the end walls or in the siege. They are substantial in design and construction; the buckstays are heavy and they are provided with the best and most approved tuile hoists and tuiles. The regenerators, flues and reversing valves are of large proportions, insuring a hot, even running furnace and a low fuel cost.

Plate Glass Annealing Kilns

Kilns for one, two or three plates each are now in general use for large plates. We have successfully applied producer gas to these kilns, by use of a special burner we employ for that purpose. We construct them for use of natural gas also, complete with all appliances.

Plate Glass Annealing Lehrs

We first adapted the Tondeur rod lehr system for the annealing of plate glass in 1898. Since that time it has been improved, until now it is used generally for most of the plate glass under 200 square feet. This was the first important innovation in that business since the adoption of the Siemens regenerative furnace many years ago.

We apply producer gas to these lehrs also, and construct them for all lines of rolled sheets, including wire glass, prism, skylight, cathedral and plate glass. We use a special heavy section lehr rod mounted on anti-friction bearings and arranged to be operated by compressed air, electric motors, hydraulic or steam power. We also provide and install mechanical stowing tools for operation with power, and a complete pyrometer system.

Glass Bending Kilns and Lehrs

These are constructed as single kilns, or a group of kilns provided with lehrs, and are used for bending both plate glass and window glass.

The lehrs are equipped with pyrometers to accurately record the temperatures and to provide for the easy regulation of uniformly graduated temperatures.

Forms for bending are provided if desired, or we can furnish rolls for bending the forms. Bending kilns and lehrs are built for use of all kinds of fuel, natural gas or producer gas, coke, coal or wood.

Recuperative Furnaces

The recuperative, non-reversible type of hot air furnace was introduced in Germany some years ago and several have been constructed in this country. They are well adapted for some styles of furnaces and, in addition to the advantage of running continuously without reversing, they are economical in consumption of fuel and substantial and durable in construction. We have the plans embodying the latest improvements and are preparing to apply it for various purposes where the reversible type of furnace is objectionable.

The End-Port Tank Furnace

Furnaces embodying the principles of the end-port tank furnace (Fig. 5) were in use many years ago, employing what is known as the horseshoe flame, wherein the ports were on one end or one side of the furnace chamber, the elements of combustion alternately entering one and passing out of the other, the direction of the flame being in the shape of a horseshoe. This style or type of tank furnace has the advantage of being less in extreme width, although of greater length than the tank with the regenerators and ports on the opposite sides of the melting chamber (Fig. 18) which makes it more adaptable to factories where a greater width is objectionable. The ports and regenerators being at the end of the melting chamber, makes it possible to arrange the shops around the gathering end to better advantage, the side or corner shops having as comfortable a place to work as any of the others. This is the chief advantage of the end-port construction, for it has been demonstrated conclusively that, for the same production, the melting chamber must be much larger than is required for the side-port tank, which results in some saving in the cost of repairs. We have both types in operation and are prepared to build either, as may be desired. We construct them for use of natural gas, producer gas or oil as fuel, and guarantee satisfactory results as to quality of glass, production, and consumption of fuel.

Gas Producers

THE steam blast, water-sealed type of producer has almost entirely superseded the old style "Siemens" and "Wellman" producers, because of its greater efficiency and the better facilities provided for cleaning while in operation.

The various types are the "Herrick," "Duff," "Dixon," "Swindell," "Wood" and others, all embodying the same general principles and differing only in the position of the grates and arrangement of hoppers and poke-holes.

We construct the "Duff" (Fig. 21) and "Dixon" producers in two sizes; the standard having a shell 10′-0″ in diameter, 11′-0″ in height; measuring 7′-0″ x 7′-0″ inside of lining and having a steel water pan 7′-0″ wide; it has a brick arched top provided with one central bell hopper and six poke-holes. The

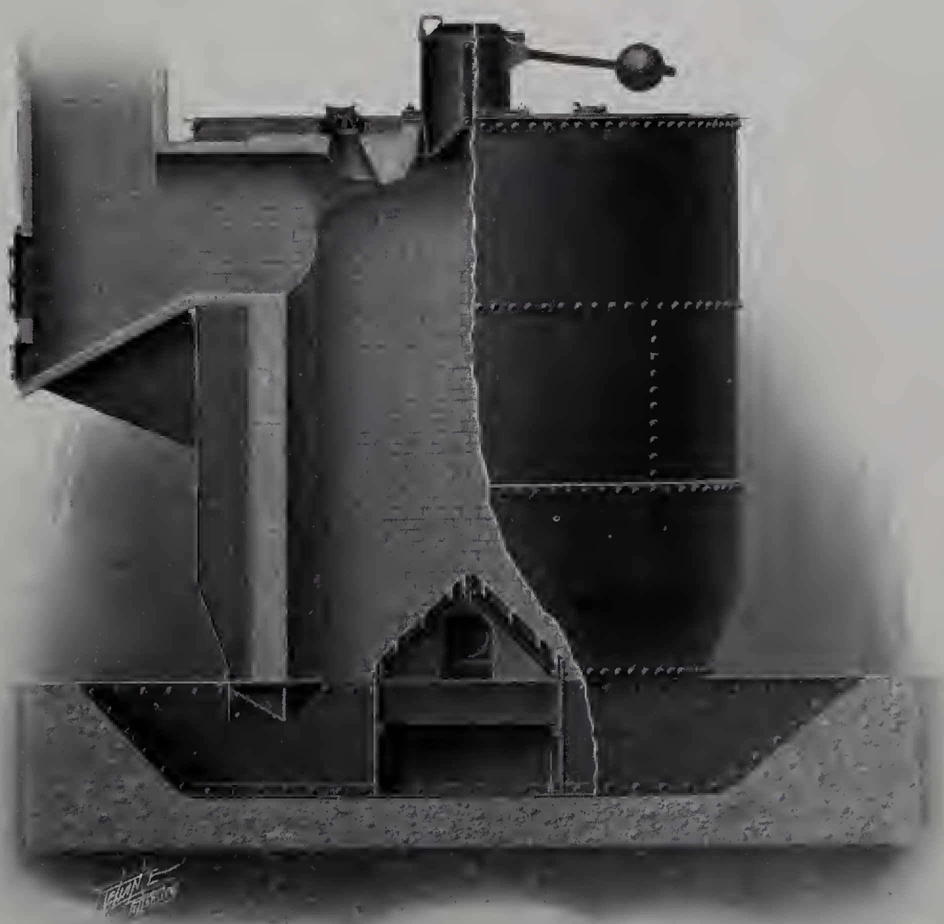


Fig. 21

Duff Gas Producer. (Elevation and Section through Neck)

large size has a shell 12′-3″ diameter, 11′-6″ in height, measuring 7′-0″ x 9′-0″ inside of lining, and having a steel water pan 9′-0″ wide; it has a brick arched top provided with two bell hoppers and nine poke-holes; it is also provided with two blow-pipes, the shells of both sizes are $\frac{3}{16}$″ gauge stiffened with angles top and bottom; the necks or outlets are of ample dimensions, constructed so they can easily be cleaned and are securely bracketed to the shells; all of the castings are of substantial weight and of the best patterns, the arrangement and construction throughout being such as to secure the maximum of efficiency with the least expenditure of skill and labor.

Herrick Patented Producers

The distinguishing feature of the Herrick Producer (Fig. 23) is the design and arrangement of the tuyeres for the introduction of air and steam into the body of the fuel.

Fig. 22–a

Brick Slotted Top Plate—Herrick Patented Gas Producer

Fig. 22–b

Quadrants, Brick Slotted Top Plate—Herrick Patented Gas Producer

The tuyeres are cast iron boxes projecting radially through the steel shell and brick lining of the lower part of the generator into the ashes.

The boxes are open at the bottom over the greater portion of the end extending into the producer, and are provided with a number of slots distributed along the sides and ends.

The arrangement of the tuyeres at equal distances around the periphery of the producer shell and each serving an equal area of the fuel bed gives an even distribution of the air and steam mixture, and all being at the same level, the height of the fuel bed above the tuyeres is uniform, resulting in equal resistance and pressure over the entire area of the bed. The water dish being open all around the producer, facilitates the uniform cleaning and removal of ashes necessary to maintain a regular and even depth of fuel.

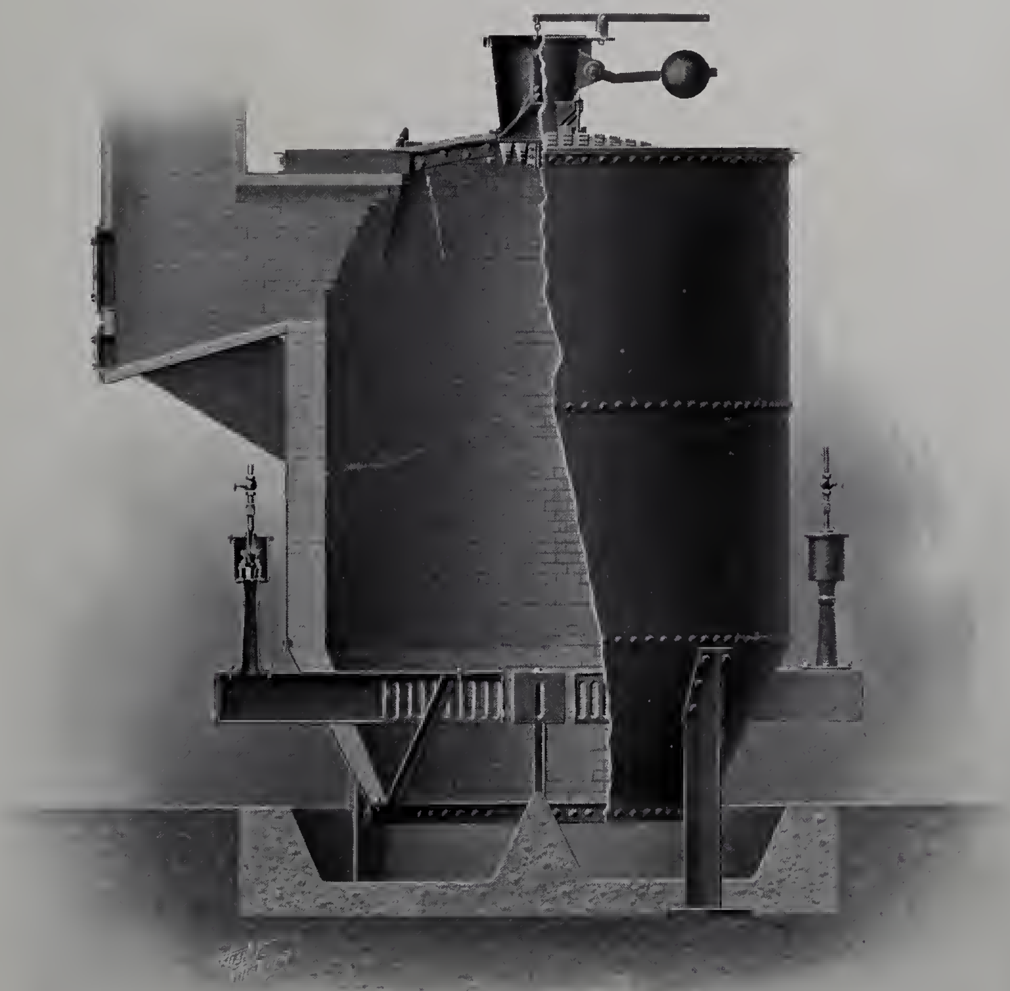


Fig. 23

Herrick Patented Gas Producer

The operation of this producer is accomplished with a very low steam pressure and, as a consequence, very little trouble from soot being deposited in the flues and conduits.

We build these of various sizes and capacities, the standard sizes being 8′-6″, 10′-0″ and 12′-0″ diameters of shells, and 13′-6″ in height. Other styles of producers may be easily changed to this type, resulting in an increase in efficiency of twenty to thirty per cent.

The tops are so constructed as to be protected from the heat, being made of heavy cast iron plates (Figs. 22), slotted for the insertion of fire brick which project both above and below the plate, insuring protection to the plate on the inside and to the feet of the stoker when standing on the top. The poke-holes are so arranged as to give a wide range to the poker, enabling the gas maker to reach every part of the fuel bed with facility, and the interior being circular in form, the distribution of the fuel is uniform and the cleaning may be done in such a manner as to constantly maintain a level fuel bed.

As the capacity and efficiency of a gas producer are in proportion to the area covered by the steam and air blast, and dependent upon an equal and uniform resistance to the pressure exerted, it is evident that the arrangement and construction of the Herrick producer insures a largely increased capacity, and greater efficiency per square foot of area, than has heretofore been attained.

The absolutely uniform height of the fire bed above the tuyere boxes, which is easily and constantly maintained, permits their operation at a maximum working condition, with a steam pressure of not over fifteen to twenty pounds, which enables the operator to avoid holes in the bed, uneven depth of fuel, and, above all, prevents the partial combustion of gas in the producers and flues, thereby avoiding the troublesome deposit of soot in the pipes and conduits. The best way to overcome the soot nuisance is not to make any, and this is one of the most satisfactory results obtained from the use of the Herrick producers.

Producer Gas Power Plants

The successful use of bituminous producer gas for the operation of gas engines has been made possible by the introduction of

a simple gas scrubbing apparatus, which may be connected with any of the ordinary gas producers now in use, for the purpose of removing all of the solid matter, such as soot, tar, ash, etc., carried in suspension by the gas from the producers. When cleansed in this manner the gas may be piped for a considerable distance through ordinary iron pipes and distributed to various points of consumption. Gas applied in this manner has resulted in the operation of power plants at as low a cost as one cent per horse power hour.

This gas is also convenient and economical for use where a large number of small fires are required for special purposes, such as small forges, annealing furnaces, finishing furnaces, gloryholes and mould heating devices, or any of the numerous processes where the additional cost of the fuel will be compensated for by a saving in labor or other advantages as compared with the cost of using solid fuel in any form.

Fuel oil atomized by use of compressed air and applied with an air blast by fan pressure to insure perfect combustion, is used extensively for the same purposes; the adaptability of both depending upon cost of fuel as compared with oil, and many other features incident to the installation and the purposes for which it is to be used.

Fig. 24

Producer Piping under Construction at the Plant of The Corning Glass Works of Corning, N. Y.

Gas Pipes, Flues and Conduits

The proper construction of the pipes, flues and conduits connecting the gas producers with the various furnaces, lehrs, etc., to be supplied with fuel, is as important as the construction of the furnaces or producers.

The tendency is to cheapen their construction by limiting their dimensions and the omission of the necessary ample provisions for burning out, cleaning, etc. We have learned by experience that this is often fatal to the successful operation of the plant, and, at best, adds largely to the expense by wasteful consumption of coal, as the result of forcing the producers, as well as by increased cost of labor.

Steel shells of producers, gas pipes and stacks should be well painted with good mineral paint once a year, at least.

Steel and Brick Stacks

We construct stacks of any dimensions, either of brick or steel, as desired. The steel stacks are self-sustaining, securely bolted to concrete or brick bases, of heavy gauge, with flared bottoms and ornamental tops, if preferred; they are provided with ladders and are lined with fire brick flush with the top.

The brick stacks are of solid walls of sufficient thickness, bound with angles and rods; or, we build them with core and air chamber, as required. They are symmetrical in shape, with suitable top trimming and have secure concrete foundations. When producer gas is used, the steel stack has the advantage of the brick stack, as the walls of the latter invariably crack, which is due to the sudden heat caused by the burning out of the flues.

Electric Drive for Glass Machinery

IN illustrating and describing modern glasshouse equipment we wish to emphasize the advantage to be derived from the use of electric motors for operating lehr machinery, rolling tables, grinding wheels, ware conveyors, batch elevators and mixers, stowing machinery, special machinery, etc.

By applying the motors to individual drive, or by locating the machinery in small groups, with a motor serving each group, an efficient, economic and highly flexible system of power transmission is obtained. Belt and shaft friction, with their accompanying dirt and danger from overhead bearings, are removed. Unsightly overhead shafting is eliminated, allowing for the installation and unobstructed passage of traveling cranes.

Where a motor is direct connected to the machine, power is being consumed only when the machine is in operation, whereas,

Fig. 25

Type "L" Direct Current Motor

in the case of belt transmission from shafting, there is a constant consumption of power due to bearing and belt friction.

We are equipped to furnish both direct and alternating current electrical machinery especially adapted to meet the practical working conditions encountered in the glass industry.

For direct current work the Type "L" motor, illustrated as Fig. 25, is the most serviceable, both for small and large capacities. Besides presenting a neat external appearance the motor is compact in its construction and designed for hard continuous service.

In Figs. 26 and 27 we illustrate two forms (Type "M," Form "R" and Form "C") of alternating current motors best suited for driving glass machinery. The principal difference between Form "R" and Form "C" motors is in the design of the rotating element (or rotor) requiring different methods of starting the motors. Form "R" (Fig. 26) motors are started by means of a lever attached to the frame, the movement of which varies the resistance in the rotating element. When starting, all of the resistance is thrown into the circuit of the rotor and gradually cut out as the motor attains its normal running speed. In the case of the Form "C" motor the starting device or compensator (Fig. 28) consists of a separate iron casing containing the starting resistance. This device may be located in any position most convenient for starting the motor. The compensation method of starting will be found very advantageous in cases where it is necessary to operate the motor upon the wall, ceiling or other inaccessible place.

Fig. 26
Type "M" Form "R" Alternating Current Motor

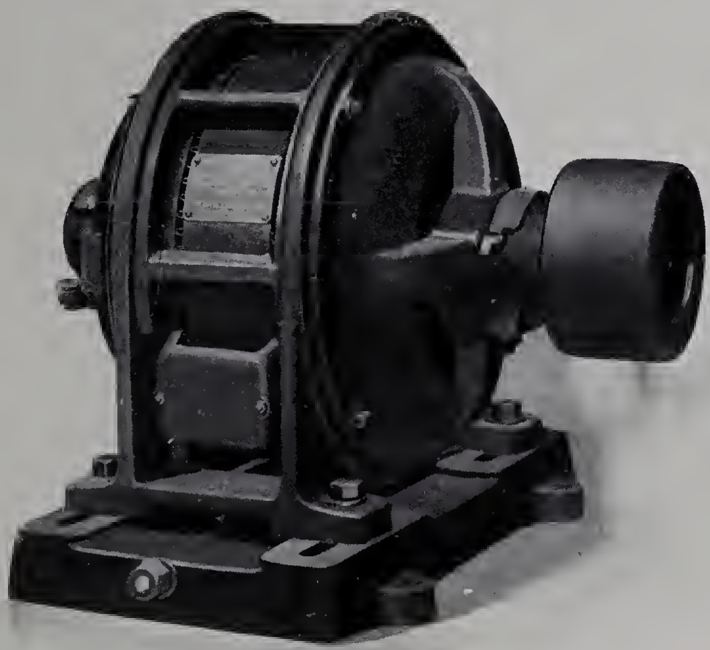


Fig. 27

Type "M" Form "C" Alternating Current Motor

Fig. 28

Starting Device or Compensator and Fuse Blocks for Type "M" Form "C" Motors

IRONWORK

Flint Glass Furnaces

Eye plates,
Cave plates,
Side plates,
Bearing bars,
Grate bars,
Cave doors and frames,
Tease-hole doors and frames,
Shadow-pan doors and hinges,
Nicholson, Gill or Murphy Producer Castings,
Rail or cast buckstays,
Hog chains and swivels,
Flat bands and collar bolts,
Cast hollow key blocks, numbered and tapped for air pipe nozzles,
Man-hole frames and doors,
Damper plates and angle frames, or "Gill" pattern cast frame and damper.

Flint Glass and Bottle Lehrs

Tease-hole Frames, tile lining, to slide on trolley, or frames with hinged doors.

Cross Ties for two, three, four or five lines of track.

Track Bars 4′-0″ long, for rollers spaced on 6″ centers.

Cast Rollers 3″ and 4″ diameter, curved face.

Angles for sides, with splices and C. S. bolts.

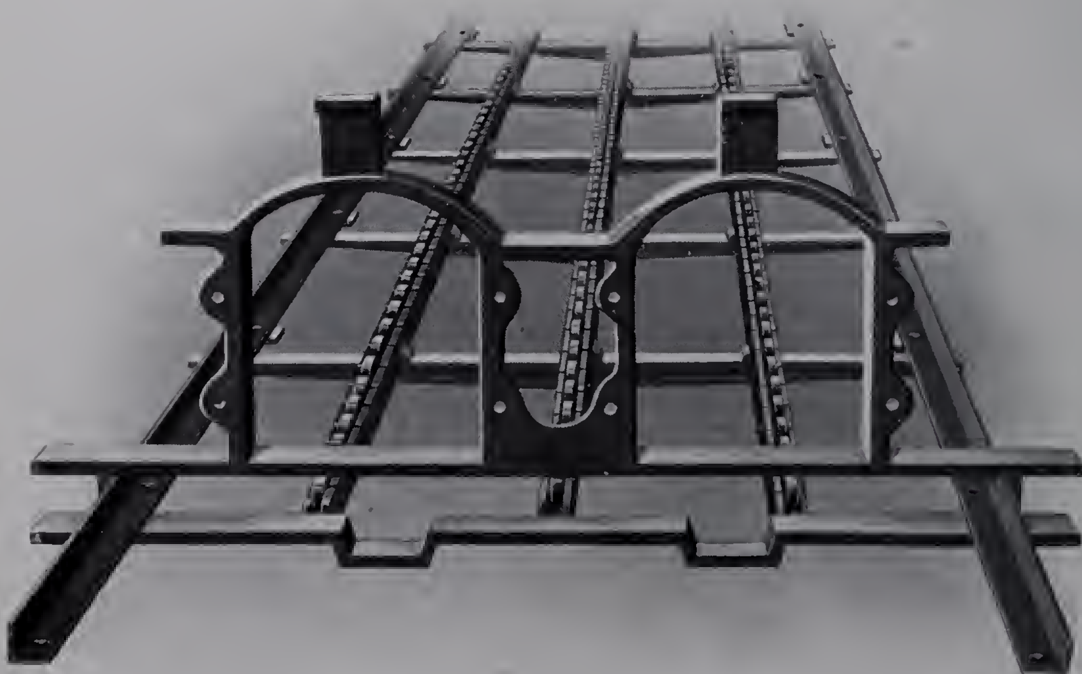


Fig. 29
Lehr Ironwork

Adjustable Self-Closing Lehr Doors

(Patented)

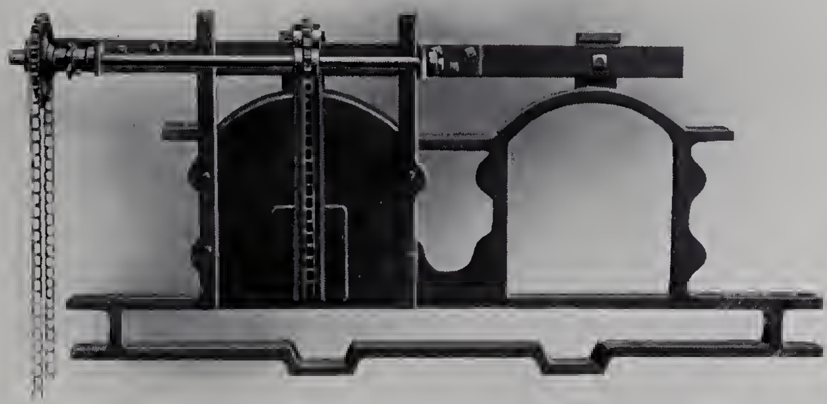


Fig. 30. Closed

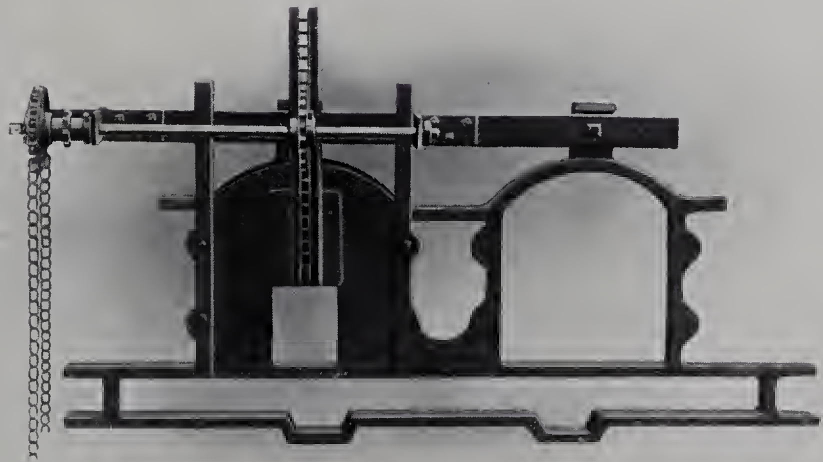


Fig. 31. Quarter Open

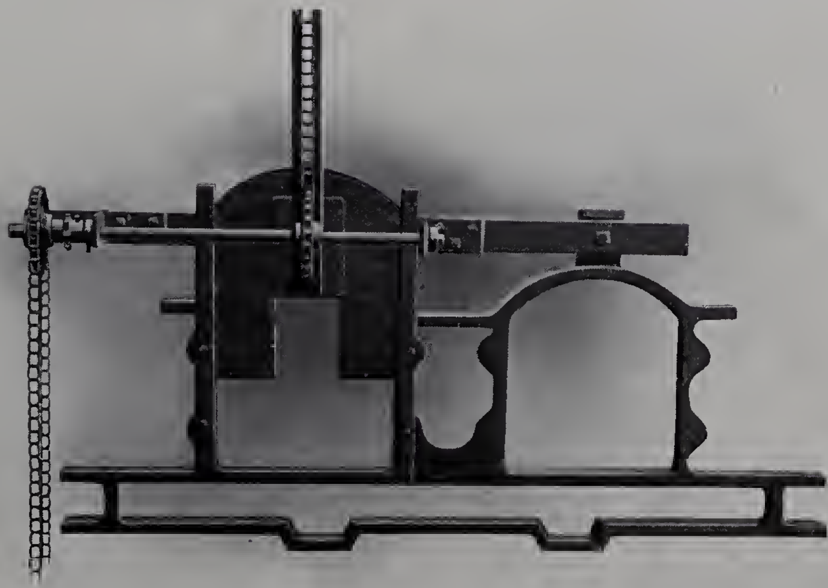


Fig. 32. Full Open

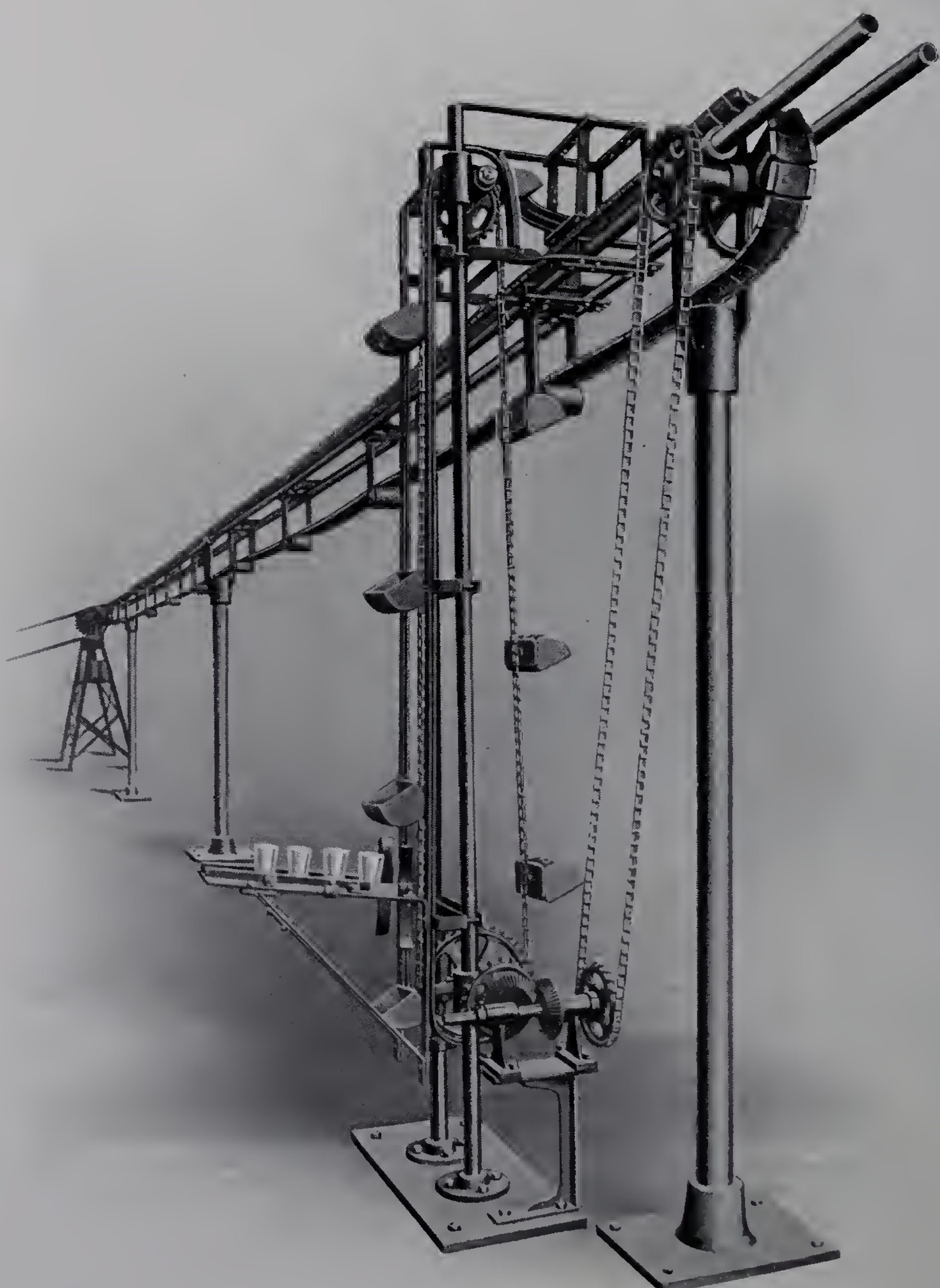


Fig. 33

Shunk Patented Carrying-in Device—"Elevator to Carrier"

Fig. 34. Shunk Patented Carrying-in Device—"Delivering End"

Fig. 35

Fig. 36

Single and Double Geared Pulling Rigs

Fig. 37
Endless Carrier for Lehrs

Front Frames. (Fig. 29). Special pattern, single or double doors.

Pan Treadles for detaching pans.

Pulling Rigs. (Figs. 35 and 36). Consisting of cold rolled shaft keyseated, stands, collars, sprocket wheels, ratchet and lever; or a set of double gears and pinions for hand power.

Worm-Gear Attachments for operating pulling rigs by electric motor; easily controlled, any desired speed.

Belt Attachment for operating by steam power, with tightener; easily operated by boy or girl.

Pan Hooks, with special steel sprocket chain.

Pan Clutch, self-locking, with trolley.

Trolley Track, single and double hangers.

Coburn Track and ball-bearing trolleys.

Stacks of sheet steel with cast iron bases.

Rear Shade Doors, with slide rods, pulleys and balance weights.

Buckstays, heel plates, tie rods, crown mantles and dampers.

Lehr Pans of No. 8 or No. 10 gauge straightened steel plates, 3′-0″ to 7′-0″ in length, 2′-6″ in width; two pulling straps, angle all around in one piece or on ends only; ends 3″ to 6″ high for bottle lehrs.

Endless Carriers for Lehrs (Fig. 37), forming continuous floor of steel plates attached to sprocket chains and running on rollers; worm-gear attachment for propelling by electric motor, intermittent or continuous movement at any desired speed.

Lehr Doors, Adjustable Self-Closing. (Figs. 30, 31 and 32). Operated by carrying-in-boy by means of treadle attachment. A great fuel saver.

Gloryholes, Pot-Arches and Mould Ovens

Gloryhole Jackets, cones and stacks of sheet steel.

Cast Iron Firm Plates, stack rings and stack bases.

Flat Bands, tool rests and natural gas burners.

Pot-Arch Buckstays, heel plates, tie rods and stack dampers.

Double Pot-Arch Doors (Fig. 38) of heavy angle frames braced with cross bars provided with clay hooks; having heavy hinge bars full width of doors and suitable latches.

Also cast iron doors with mitred flanges for brick lining.

Front Buckstays of cast iron (Fig. 38) with heavy rib and hinge lugs for hanging doors. Also rail buckstays with adjustable hinge lugs.

Mould Oven Carriages (Fig. 39) with tee rail tops, steel axles and cast flanged wheels, with tracks and spreaders.

Heavy Sheet Steel Doors for mould ovens with hinge straps and latches; buckstays, tie rods, heel plates and stack dampers. (See also Fig. 4.)

All of the best patterns and designs, and of substantial weight and workmanship.

Any special design or pattern made to order.

Fig. 38

Ironwork. (Pot-Arch Doors and Cast Buckstays)

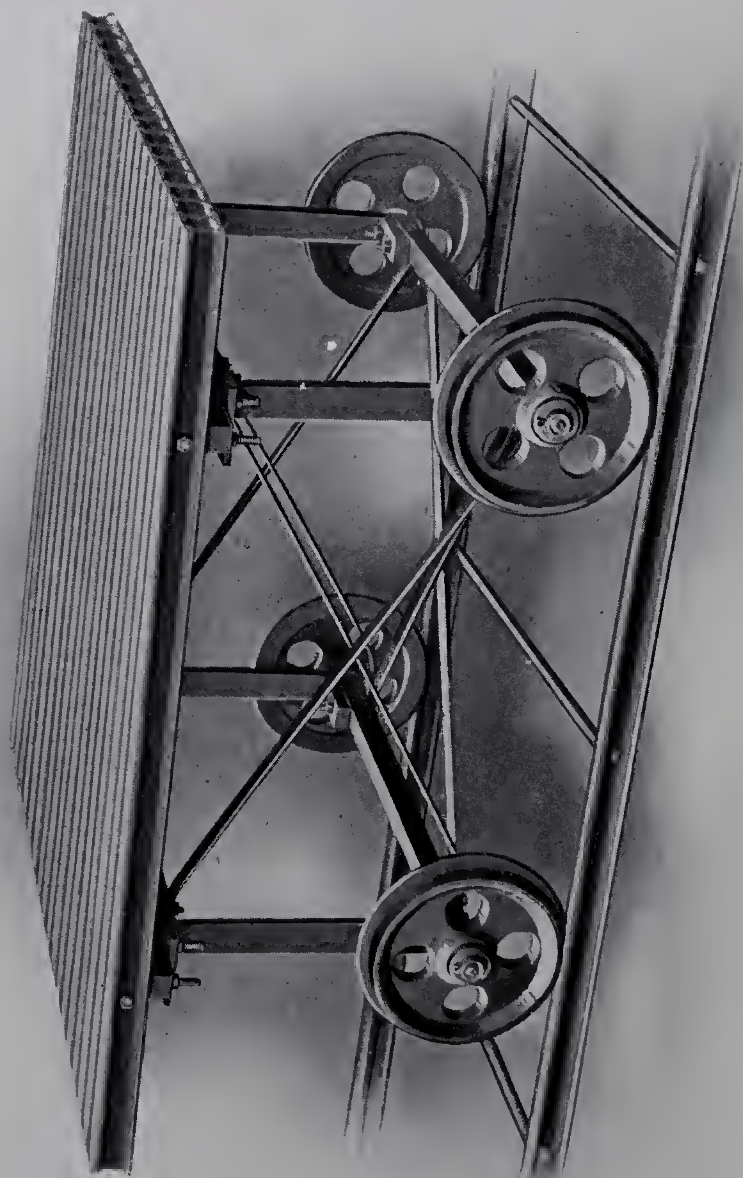


Fig. 39
Mould Oven Carriage

Tanks and Furnaces

Ironwork for daily or continuous melting tank furnaces for all purposes, of standard patterns or of any special sizes or patterns to order.

Rail, double channel or eye beam buckstays.

Breastwall Plates and brackets, cast or wrought.

Angles and adjustable screw brace bolts.

Heel Plates, bands, hog-chains, beams and tie rods.

Batch Filling Shovels, either mounted on rollers on stationary stands, with levers and balance weights for filling hole doors; or filling shovels hung on swinging cranes, with crane post, guy rods, footstep and balance weight; also filling hole door frames hung on chain with suitable pulleys and balance weights.

Screw Stands, pulleys, brackets and all attachments for operating dampers.

Levers and appliances for reversing valves.

Burner Nipples of cast iron for natural gas; stack and air regulating dampers.

Decorating Ovens and Staining Kilns

The Ironwork for Decorating Lehrs is similar to that used in the construction of the ordinary lehrs for annealing flint glassware.

Heavy Cast Iron Frames and Doors for tile lined decorating ovens; frames boxed for building in wall with lugs extending back of buckstays and provided with hinge lugs for doors; doors each in four parts, two upper and two lower, each with heavy hinges and latch and having mitred flange inside to hold brick lining; all doors provided with peep-holes and toggles.

Tease-Hole Frames and Doors for coke firing, either cast iron frame with hinges, brick-lined door, or wrought frame, tile lined, hung on trolley.

Sheet Steel Shells, from No. 8 gauge up to ½″ boiler plate, either circular or elliptical in form, or with straight bottom and sides with curved top; provided with cast iron front frames with cast or sheet steel doors in two or four parts, to swing on hinges and having peep-holes and toggles; angles 1½″ x 1½″ riveted on inside of shells to hold ware pans, if desired.

Perforated Sheet Steel Ware Pans, cast iron stools for pans. All buckstays, tie rods, heel plates, angles, grate bars and stacks.

Window Glass Flattening Ovens and Lehrs

Flattening Wheels or Turntables in three sizes, 14′-9″, 16′-0″ and 18′-0″ diameters, consisting of heavy cast iron segments securely bolted to hub, upright shaft, and covered with perforated cast iron plates; upright shaft provided with footstep, bevel gear with guy rods; turning gear, consisting of counter shaft with bevel pinion, stand, wall plate and pilot wheel. Cast iron or rail mantles with mantle rods attached to beams on top of oven, flattening and piling bucks, glass chutes with door, shove-horse and track with stand for handle, rail buckstays, heel plates and tie rods; also crown mantles and cast iron frames and doors for lehrs. Lehr machinery, consisting of two sets of reciprocating rods, one set mounted on anti-friction sheaves on stands attached to double channels resting on lehr walls; one set mounted on stands attached to cross bars hung on stirrups, at each end, connected with lifting levers operated by connecting rods on top of lehr; all lifting boxes are provided with three armed levers and balance weights of cast iron; lehr rods are of cruciform shape, one set moving only vertically, the other set moving only longitudinally, so that they are always level and with sufficient clearance to operate without danger of scratching or of slewing the sheets out of position. Any of the parts for oven or lehr furnished on application. Other sizes than those above mentioned made to order.

Window Glass Blowing Furnaces

Ironwork for Blowing Furnaces, double or single side, either straight or curved, consisting of rail buckstays drilled for trefers, channel heel plates, tie rods, braces and pipe rests for pipe heating furnaces and iron supports for foot benches.

Floater Kilns, Block and Brick Kilns

Ironwork for Floater Kilns, Block and Brick Kilns is fabricated for kilns of various sizes and forms; some with stacks on top of kilns, others with separate stack for one or more kilns. Rail buckstays, channel heel plates and tie rods; double doors of heavy angle frames and cross bars with clay hooks, hinges and latch; doors hung on heavy cast or rail buckstays; damper frame, damper, lever and chain for top of stack, or damper hung on chain with pulley and balance weight for separate stack.

Cruciform Bars for Window and Plate Glass Lehrs

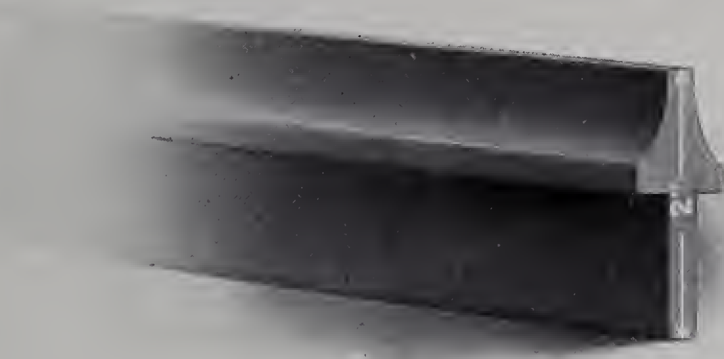


Fig. 40

Fig. 41

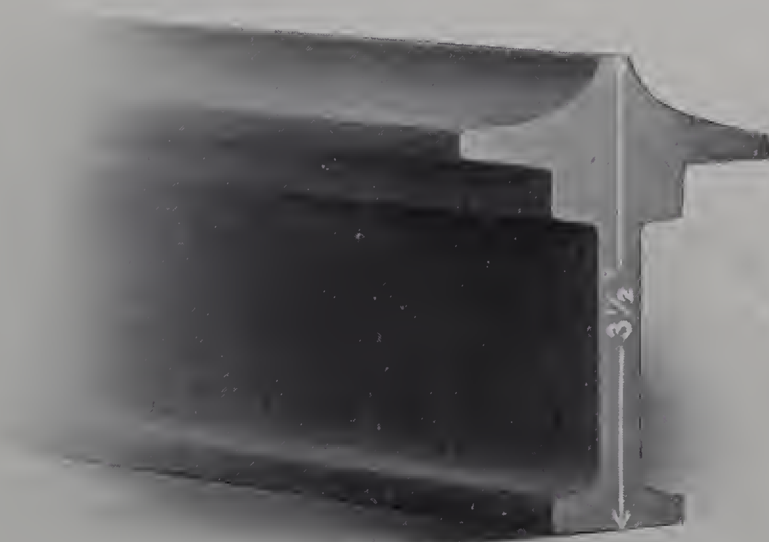


Fig. 42

Plate Glass Furnaces

Double Channel Buckstays with spreaders and lugs for tuile bars.

Also tie rods, hog-chains, swivels, turnbuckles and washers.

Tuile bands and bars.

Fig 43
Screw Stand

Tuile Hoists, consisting of bevel gear attachments on brackets with cranks and ratchets for operation by hand, or with devices for operating by motors; shafts and pillow blocks with chain sheaves, tuile chains and balance weights, all supported on beams over crown of furnace attached to buckstays; or with pipe shafts for winding chains, all of best patterns and latest design.

Floor Plates in all sizes made of cast iron.

Plate Glass Kilns and Lehrs

Kiln Doors of heavy sheet steel, well bound and stiffened with angles, provided with Z bar slides, wire ropes, sheaves and balance weights.

Dampers and Frames of cast iron for kilns.

Man-Hole door frames and doors.

Burners of special design for producer gas.

Sills of cast iron for push-holes.

Mantles with hoisting doors with levers and balance weights, for push-holes of lehr ovens.

Boxed Frames with hoisting doors with levers and balance weights for stowing holes.

Lehr Machinery of special design with rods of special heavy section.

Cylinders and Motors with all attachments for operating lehr machinery by hydraulic or electric power.

Fig. 44
Screw Stand and Cover for Mushroom Valve

Stowing Tools with all devices and machinery for operating by electric motors.

Rolling and Stowing machinery, electric driven.

Doors of Cast Iron with mitred flanges for brick lining, heavy hinge lugs and latches, for pot ovens.

Pot Oven Doors of heavy angle frames and cross bars with clay hooks for clay lining; having heavy hinges and latches.

Buckstays of rails, beams or channels; cast or channel heel plates and tie rods with washers and turnbuckles, for kilns, lehrs and pot ovens.

Ironwork for Plaster Kilns, rouge ovens, and for bending kilns and lehrs.

Ironwork for tank block and floater kilns.

Gas Producers, Pipes, Flues and Stacks

Steel Water Pans, ¼″ boiler plate.

Steel Shells for producers, $\frac{3}{16}$″ and ¼″ gauge, with angles around top and bottom.

Necks or outlets, No. 8 and 10 gauge, with steel angles or flanged corners.

Main Gas Pipes, No. 8 gauge, stiffened with angle rings.

Branch Pipes, mushroom boxes, down-take pipes, No. 8 gauge or No. 10 gauge, according to size. All seams of good pitch and securely riveted.

Stacks, flared at bottom, self-sustaining; gauge of steel to suit diameter and height; ornamental tops if desired,; provided with ladders, base plates, anchor bolts and washers.

Wall Bearing Plates of cast iron, blow pipes on hinged frames and grate castings.

Stands and Screws (Figs. 43, 44 and 45) with hand wheels for operating dampers.

Bell Hoppers with lids, levers and balance weights.

Sand Dampers and frames.

Poke-Hole castings and covers (Fig. 46).

Mushroom or saucer valves and seats (Figs. 47 and 48).

Cleaning Doors (Figs. 50 and 51) and puff doors and frames with straight or curved backs for vertical or horizontal pipes.

Valve Stems, stands, pulleys, wire ropes with clips and thimbles and winches (Fig. 52) for elevated dampers.

Man-Hole Covers and seats for brick flues.

Puff Doors with boxed frames for brick flues.

Saucer Valves for brick flues, with seats, covers, stems, stands, screws and hand wheels.

Patented Air Mixer Burners (Figs. 53, 54 and 55) for lehrs, with air pipes.

Producers, gas pipes, stacks and appliances, also steam blowers (Fig. 49) of any special design and for all purposes, furnished on cars, knocked down; or will take measurements, make plans and contract for erection complete.

All parts for renewals or repairs furnished promptly on application.

Mineral Paint of excellent quality, in barrels.

Steel Pokers with long handles, cleaning shovels with perforated blades, coal shovels, steam blast nipples, regulating valves for steam pipes.

Endless Chain Conveyors for removing ashes, for operation by motors, steam or gas engines.

Fig. 45

Screw Stand for Stack Damper and Mushroom Valve

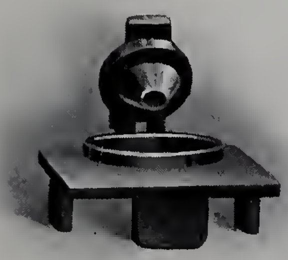


Fig. 46

Poke-Hole Casting and Cover

Fig. 47

Mushroom Valve and Seat

Fig. 48

Mushroom Saucer Valve

Fig. 49

Steam Blower for Producers

Fig. 50.

No. 9 Cleaning Door

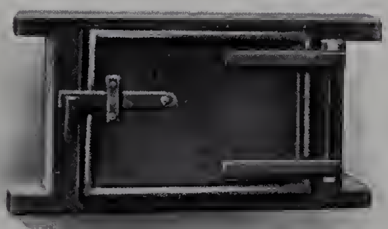


Fig. 51

No. 10 Cleaning Door

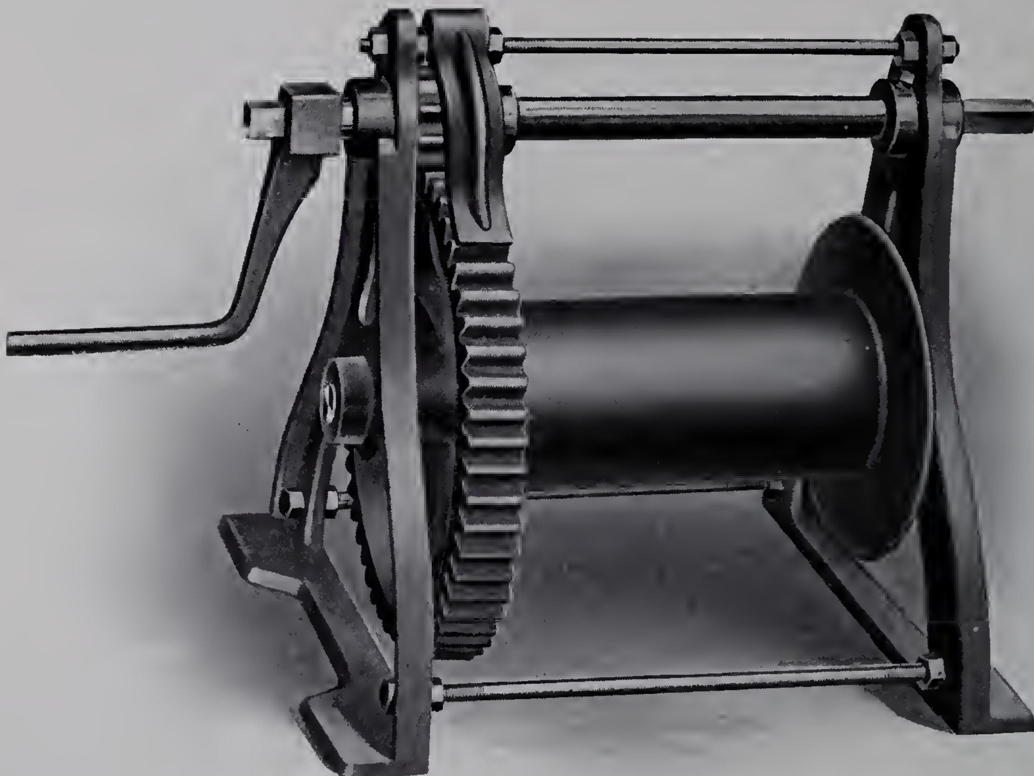


Fig. 52. Winch

Fig. 53
Detail of Patented Air Mixer Burner

Fig. 54. Front View of Burners

Fig. 55. Rear View of Burners

Patented Air Mixer Burner for use with producer gas in firing lehrs

TOOLS AND IMPLEMENTS

Flint Glass Factories

Fig. 56. Blocking Box

Pot Carriages in all sizes, with heavy steel prongs, extension handles, wheels 24″ diameter, 4″ face.

Steel Pot-Setting Bars (Fig. 62) in various sizes, chisel and pick points:

18′-0″ long, 2½″x2½″, with rounded handle tapered to 1¼″.

16′-0″ long, 2¼″ x 2¼″, with rounded handle tapered to 1¼″.

12′-0″ long, 2″ x 2″, with rounded handle tapered to 1¼″.

10′-0″ long, 1½″ x 1½″, with rounded handle tapered to 1″.

8′-0″ long, 1½″ x 1½″, with rounded handle tapered to 1″.

Lazy-Bones for Pot-Setting (Fig. 57), made of heavy steel frame, well braced and provided with three rollers for cleaning bars.

Lazy-Bones for Building Breastwalls with three roller bearings.

Block Carriages, two wheels, for setting breastwall blocks.

Brick Forks (Fig. 58), two prongs, for setting jack brick.

Clay or Brick Paddles with sheet steel blades.

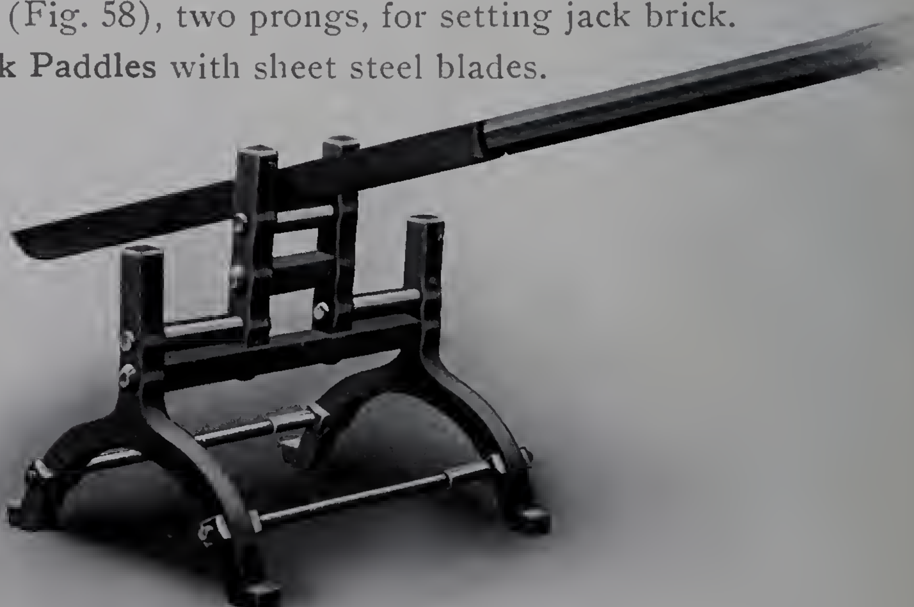


Fig. 57 Lazy-Bones

Pot-Setting Tools

Fig. 58. Brick Fork

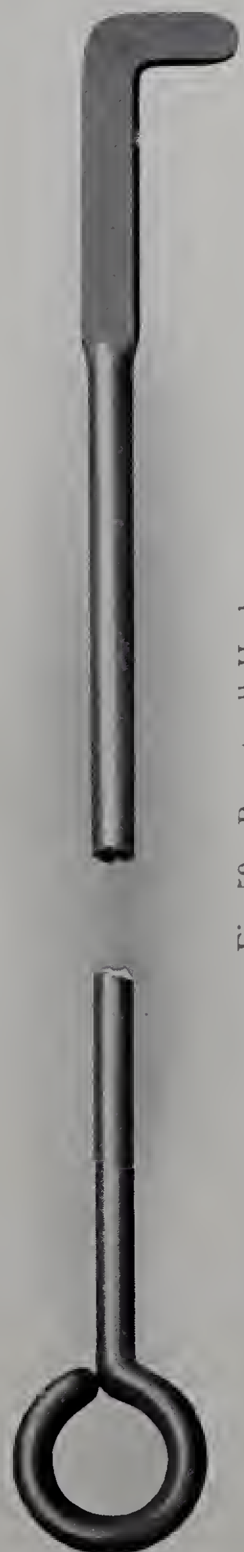


Fig. 59. Breastwall Hook

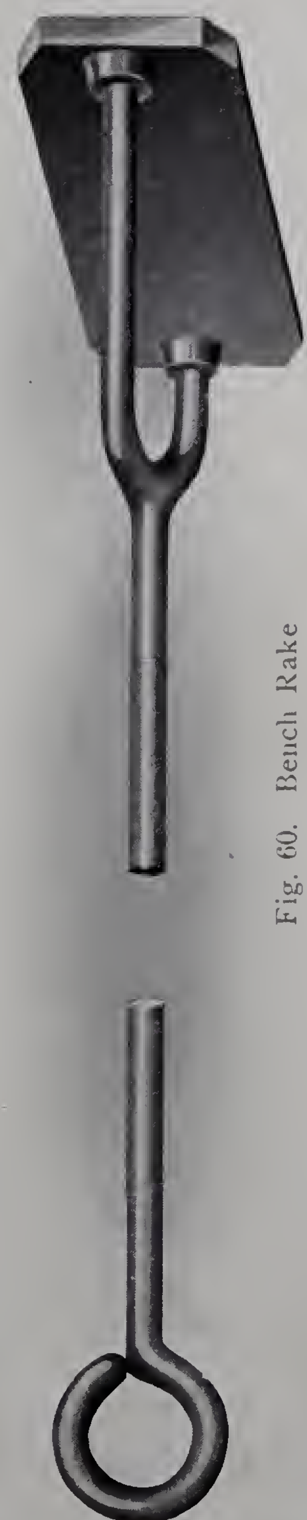


Fig. 60. Bench Rake

Fig. 61
Pot-Setting Carriage. (Large Size)

Fig. 62
Pot-Setting Bar

Fig. 63
Carriage for Setting Monkey-Pots

Fig. 64. Shadow Pan

Sponge Poles, tapered flat blades.

Bench Repair Paddles, 18′-0″ long, steel blades 6″x12″x¾″.

Gatherers' Blocking Boxes, with or without legs.

Bench Rakes (Fig. 60), 20′-0″ long, steel blades, 6″ x 12″ x ¾″ loop handles.

Brick Rakes, 8′-0″ long, steel blades, 4″ x 10″ x ½″, loop handles.

Breastwall Hooks (Fig. 59), 10′-0″ and 14′-0″ long, 6″ tapered hooks, loop handles.

Nigger Heads 1½″ x 3½″ x 5″, with handles 10′-0″ long.

Shade Pans for pot-setting, with chains, pulleys and balance weights.

Fig. 65. Knob Kettle

Fig. 66. Pot Scraping Ladle

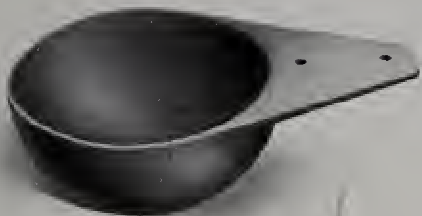


Fig. 67. Round Ladle

Fig. 68. Oval Ladle

Fig. 69. Rectangular Ladle

Bench Bar (long).

Knob Kettles (Fig. 65), square or round.

Gathering Pigs, cast or wrought iron.

Scraping Ladles (Figs. 66 and 69), forged steel with handles.

Ladles, forged steel, 6″ x 10″ x 3″ deep, with handles.

Ladles, forged steel, round (Fig. 67) 6″ to 10″ diameter, or oval (Fig. 68), with handles.

Large Ladling Kettles (Figs. 72, 73 and 74), on frames with three wheels each, front wheel on swivel, frames for either stationary or tilting kettles in two sizes, 42″ diameter, 22″ deep and 38″ diameter, 20″ deep.

Small Ladling Kettles (Fig. 70) with three wheels, two on cast lugs, other wheel on swivel.

Fig. 70
Small Ladling Kettle

Fig. 71
Bit Kettle

Ladling Kettles

Fig. 72. Tilting Ladling Kettle
(Normal Position)

Fig. 73. Tilting Ladling Kettle
(Tilting Position)

Fig. 74
Non-Tilting or Stationary
Ladling Kettle

Fig. 75. Bit Kettle

Bit Kettles (Figs. 71 and 75), 22″ diameter, 14½″ deep, with marver plates, on three wheels each, one wheel on swivel.

Marver Plates, one side and one edge planed.

Water Boshes, cast iron or sheet steel, various sizes.

Finishing Tools.

Snaps, all kinds.

Cleaning-off Chests
(Round Pattern)

Fig. 76

Fig. 77

Fig. 78

Cleaning-off Chests

Fig. 79

STEEL BATCH CARTS

STANDARD TYPE

BODY is made of No. 10 and No. 12 Gage Blue Annealed Sheet Steel, strongly reinforced with riveted steel angles and side stakes. An extension bottom and adjustable slide in end gate are provided for removing batch without spilling.

Made with plain bearings or with roller bearing wheels and ball bearing front swivel.

Size of body, 23 inches deep, 36 inches wide, 78 inches long over all.

LIGHT --- STRONG --- DURABLE

WILL NOT LEAK BATCH

SPECIAL CARTS

WE are prepared to make batch carts to meet special conditions and if our standard cart does not meet with your requirements we would appreciate an opportunity of making suggestions.

The cut illustrates a cart which we furnish to some of our customers, omitting the front swivel and handle and provided with tubular shafts and rest.

Fig. 80. Batch Cart

Cleaning-off Chests (Figs. 76, 77, 78 and 79), round or square.

Batch Cart (Fig. 80), well braced and bound with iron, with iron wheels, 24″ diameter, 4″ face, beds 5′-6″ long, 2′-10″ wide, 1′-10″ deep, inside measurements.

Gatherer's Shadow Pan (Fig. 64), for pot mouths, sheet iron, well bound..

Finisher's Chairs (Figs. 82 and 83), braced with rods and bolts.

Hot Stoves (Fig. 85) and ware pans for blown ware, with gas burners.

Fig. 81. Pot Truck

Fig. 82
Finisher's Chair. (Straight Arm)

Fig. 83
Finisher's Chair. (Curved Arm)

Sand Box Ware Stands, round or square, on legs.

Ware Stands with solid tops.

Pot Trucks (Fig. 81), convenient for handling pots from cars or pot-room to pot-arches; oak plank tops, heavy steel axles, low broad wheels, front wheel on swivel, movable handles; truck can be turned in space equal to size of the pot.

Pot Puller, lever and dog for sliding pots in car or on floor.

Gloryhole Pigs (Fig. 84).

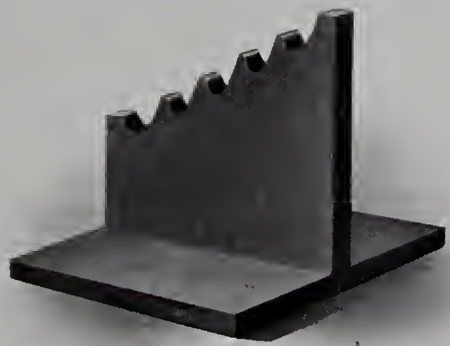


Fig. 84. Gloryhole Pig

Fig. 85. Hot Stove

Fig. 86

Blower's Dummy, Bulbs, Punch Tumblers and
Small Paste Mould Ware

Fig. 87
Blower's Dummy, Large Paste Mould Ware

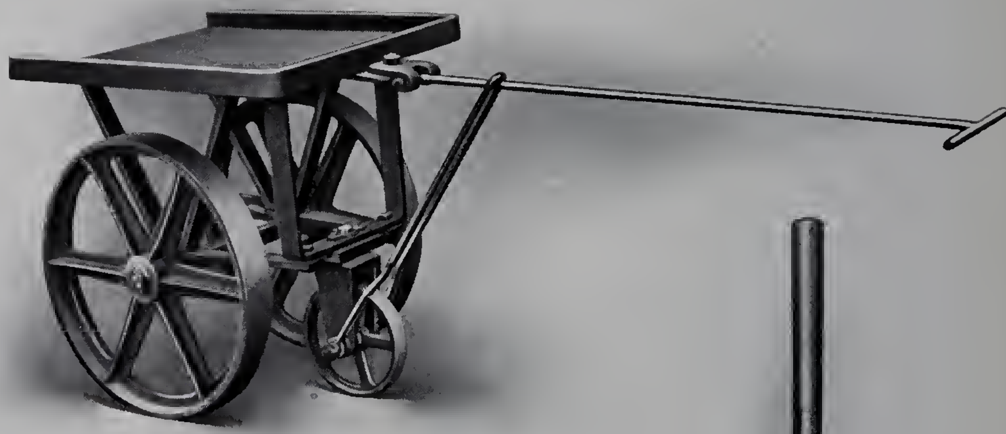


Fig. 88
Mould Transfer Carriages

Mould Transfer Carriages (Fig. 88); two wheels, short handles.

Wind Pipes of galvanized iron, 18 to 26 gauge, with 3″ nozzles with caps, or with automatic self-closing nozzles, 1″, 1¼″ and 1½″ diameter, nozzles furnished separately if desired.

Batch Mixers of improved type, for operation by steam or electric power.

Small Portable Gloryholes on wheels; suitable for tumblers, lamp chimneys, etc.

Glass Blowers' Pipes (Fig 89), punties (Fig. 90), finishing tools, snaps, clamps, shears and crimping machines.

Pressure or Volume Blowers for operation by steam or electric power, directly connected or by single or double belts (American, Andrews & Johnson and Sturtevant).

Fig. 89
Blow Pipe

Fig. 90
Puntie

Flint Glass and Green Bottle Factories

MANY of the tools and implements for bottle factories are similar to those already enumerated for flint glass factories, with some modifications to suit the practice in bottle factories.

Portable Gloryholes (Fig. 91), for use of natural gas with air blast, or for use of oil with compressed air or fan pressure. Each gloryhole is suitable for two shops and made with single or double chamber, the latter enabling each finisher to regulate his fire to suit himself without interference with the other shop. These gloryholes are substantial in their construction and the tile can easily be removed and replaced. Pipe rests are provided on each side bracketed to the bed plate.

Peanut Roasters (Figs. 93, 94 and 95), on legs; for natural gas or oil.

Ware Pans, and carrying-in tools for peanut roasters.

Carrying-in Tools, paddles or forks of all kinds.

Ware Pans, solid or latticed, for use in lehrs.

Stands for bottle snaps and tilting bottle racks, very convenient for large bottles.

Cleaning-off Chests, circular or square, for attaching to foot bench, occupy little room and are very convenient.

Cullet Boxes, square or circular, with handles.

Finisher's Chairs, peanut roasters, ware pans and carrying-in tools.

Carrying-in Paddles, asbestos lined and forks wound with asbestos.

Blow Pipes, snaps and finishing tools.

Blue Marver Stones.

Cast Iron Marver Plates, planed and smoothed.

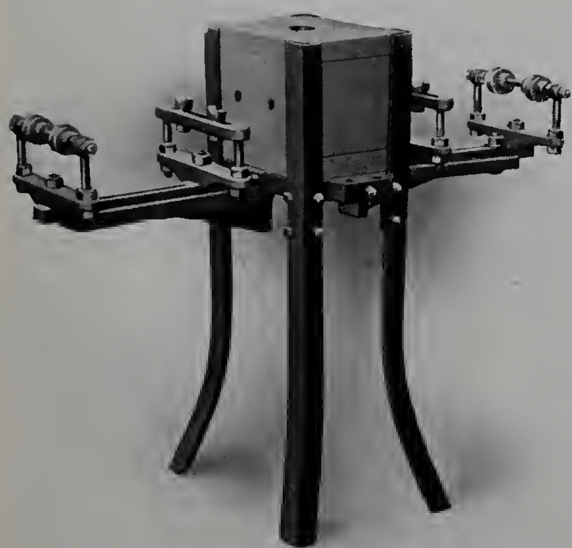


Fig. 91
Portable Gloryhole

Fig. 92
Gloryhole Burner for Oil
(Gravity System)

Peanut Roaster

Double Deck for Gas Fuel

Fig. 93

Peanut Roaster

Double Deck for Oil Fuel

(Patent Applied For)

Fig. 94

Fig. 95

Peanut Roaster. (Single Deck) For Gas Fuel

Window Glass Factories

Fig. 97
Cooling Bosh

Cranes (Fig 96), both long and short, for use on blowing furnaces or blow-over tanks; crane posts of extra heavy pipe, extension arms for cranes, with pipe crotches or wheels.

Trefers with slotted holes to attach to buckstays and provided with extension arms. Also trefers of special pattern for gatherers on tank furnaces.

Firm Plates of cast iron with crotches for gatherers.

Shades with cross bars, brackets, levers and balance weights for blowers' and gatherers' ring holes.

Cooling Boshes (Fig. 97) for gatherers for continuous flowing water with waste pipe for overflow and bracket for glass block.

Ladles of pressed steel, 20″ diameter, with handles and chain hung from Coburn ball bearing trolley and track, with hangers; rigged either for single ladle or for two ladles with double tracks and trolleys.

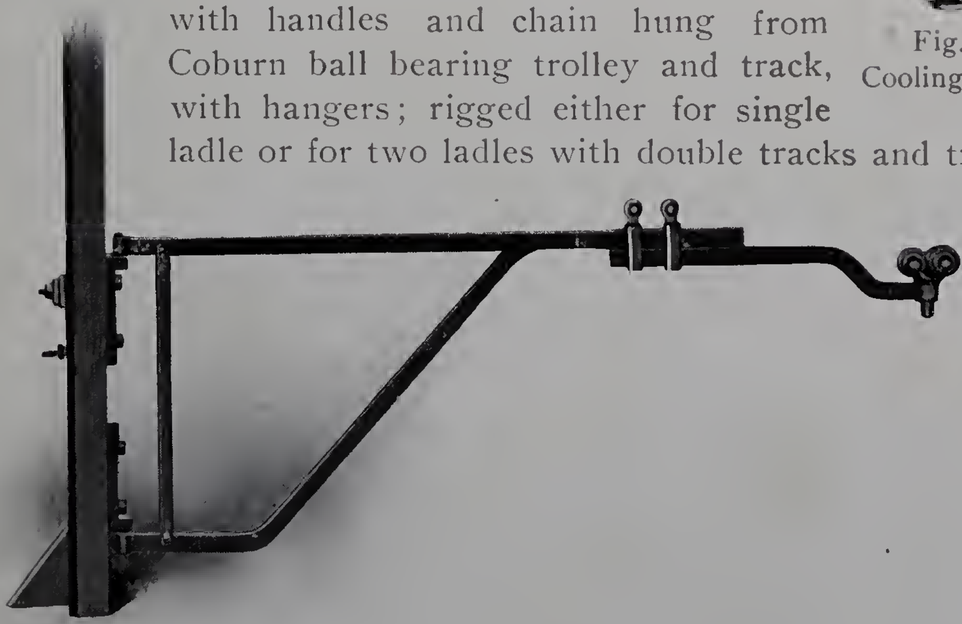


Fig. 96. Long Crane

Filling Shovels (Fig. 100) on cranes, complete with crane post, guy rods and balance weight.

Ladling Kettles on frames with three wheels (Figs. 72, 73 and 74), one wheel on swivel; two sizes, 42″ diameter, 22″ deep, and 28″ diameter, 20″ deep, either tilting or stationary.

Capping Boxes (Figs. 98 and 99) of heavy sheet steel, single boxes, 14″ bottom width, 16″ top width, 36″ long and 15″ deep; double boxes 6′-0″ long all provided with handles and bound around the top with flat bar securely riveted to box.

Novel Boxes (Fig. 101), 18″ x 30″, 20″ deep (Fig. 102), 24″ diameter and 20″ deep.

Flatteners' Cullet Boxes, 16″ top width, 14″ bottom width, 36″ long, 15″ deep, bound around top with flat bar and provided with handles.

Roller Horses, all of wood, or of steel frames with wooden roller rests.

Floater Carriages (Fig. 104) of substantial steel construction with heavy forged steel prongs, heavy axle and iron wheels with broad face.

Prongs suitable for attachments to old pot wagons, furnished on application.

Tools for setting floaters and rings as follows:

Large Bull Hooks (Fig. 109), 18′-0″ long, 1½″ round, two prongs.

Fig. 98

Fig. 99
Capping Boxes

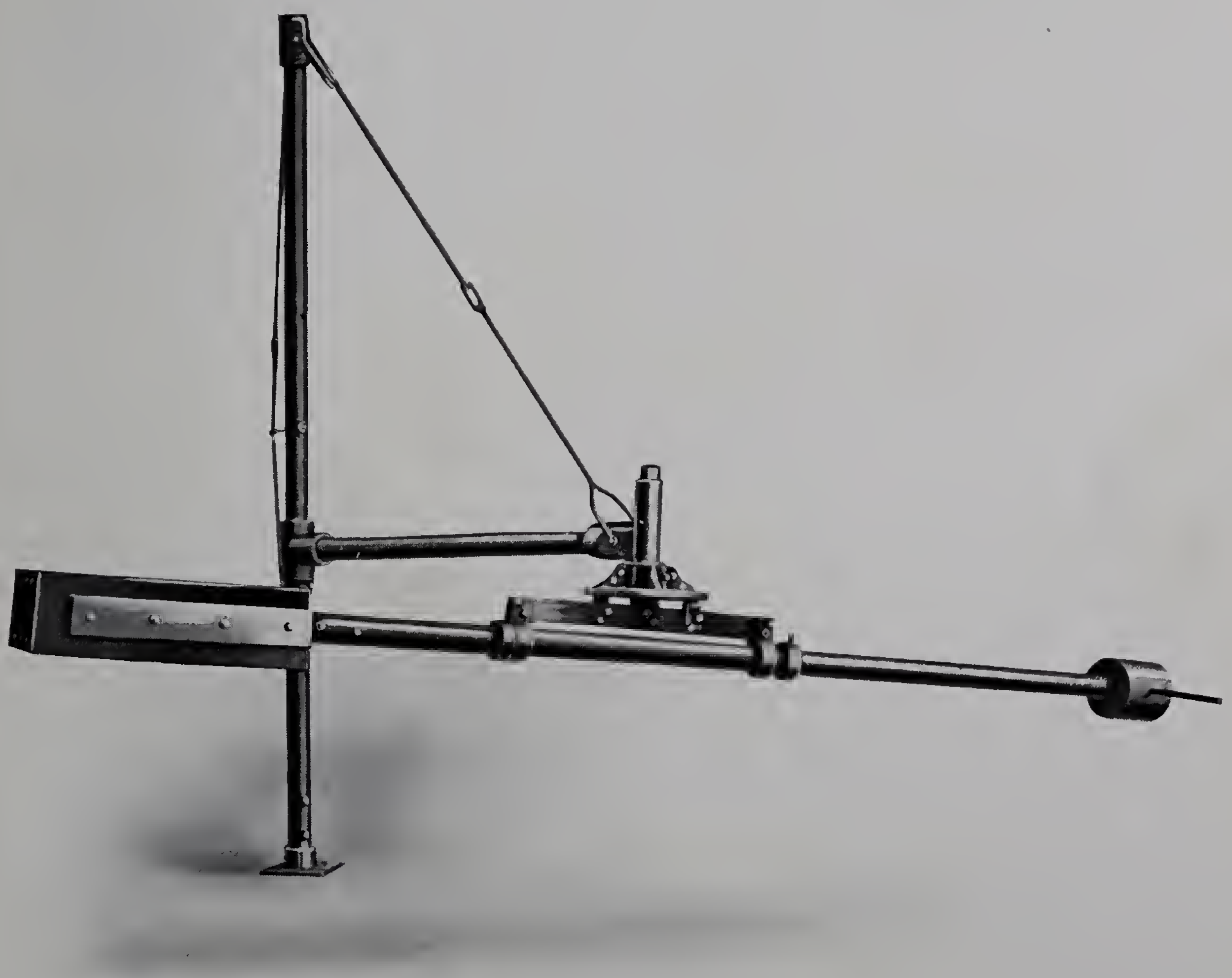


Fig. 100
Batch Filling Shovel

Fig. 101
Novel Box (Square)

Fig. 102
Novel Box (Round)

Bull Hooks, 18′-0″ long, 1½″ round, single prongs.

Single Hooks, 16′-0″ long, 1½″ round, with loop handles. Also 12′-0″ long, 1¼″ round, loop handles.

Steel Bars 18′-0″ long, 2½″ x 2½″, with rounded handles tapered to 1¼″.

16′-0″ long, 2¼″x2¼″, with rounded handles tapered to 1¼″.
12′-0″ long, 2″ x2″, with rounded handles tapered to 1¼″.
12′-0″ long, 1½″x1½″, with rounded handles tapered to 1″.

Fig. 103. Roller Wagon

Ring Hooks (Fig. 111), 10'-0" and 12'-0" long, 1" round, loop handles.

Skimming Irons, cracking irons, ring irons, ring crotches, pinchers, glass blocks and blow-up blocks.

Roller Wagons (Fig. 103), with steel springs, wooden frame.

Blowers' Pipes with Norway iron heads, finished and polished complete with handles.

Pipes without heads, polished or unpolished.

Flatteners' Tools, consisting of:

Piling Forks (Fig. 106), with tines of spring steel drawn down; either of one piece or with tines riveted on; handle of heavy pipe with weight at end.

Spiece (Fig. 105) drawn down tapering, with screw on end.

Cropper (Fig. 110) with pipe handle.

Stone Scraper (Figs. 107 and 108) with steel blade.

Swab Rods with hooks and handles.

Glass Dips with acid tank, single glass rack or with reels, provided with pulleys, wire ropes and winches.

Cutters' Tables, squares, pins and rules.

Cutters' Cullet Boxes, of wood or iron, on wheels.

Heating Stoves, natural gas, for cutting rooms.

Lubricating Soap, pipe handles, Norway iron for pipe heads.

Cutters' Pliers or pinchers, 7" to 10".

Casting Tables (Fig. 112) on wheels, built up in sections, or in one solid plate.

Rolls for operation with chain, wire rope or cog-racks.

Steel Twangs, all gauges. Turtle wagons.

Steel Table Blades, finely finished and polished.

Pot Clamps for teeming with traveling or boom cranes.

Pot Wagons or clamps for traveling cranes.

Stowing Tools for motors or hand power.

Glass Spreaders with copper blades.

Filling-in Shovels, skimming irons, batch carts.

Glass Ladles, pressed steel (Fig. 114), up to 28" diameter, with or without handles.

Coburn Trolleys and tracks (Fig. 141) for carrying ladles.

Cutters' Rules and Squares, all sizes, with brass tips.

Cutters' Pinchers or pliers, round or flat tips, 7" to 11".

Floater Carriages (Fig. 104), hooks and bars for setting floaters.

Fig. 104
Floater Carriage

Fig. 105. Spiece

Fig. 106. Piling Fork

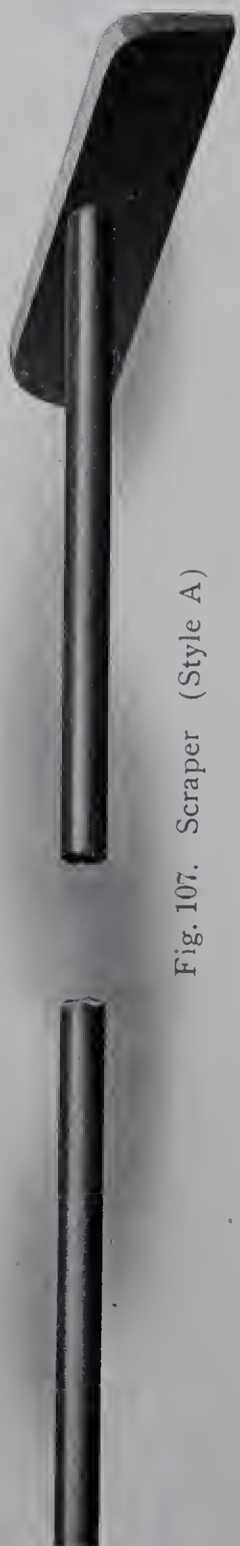


Fig. 107. Scraper (Style A)

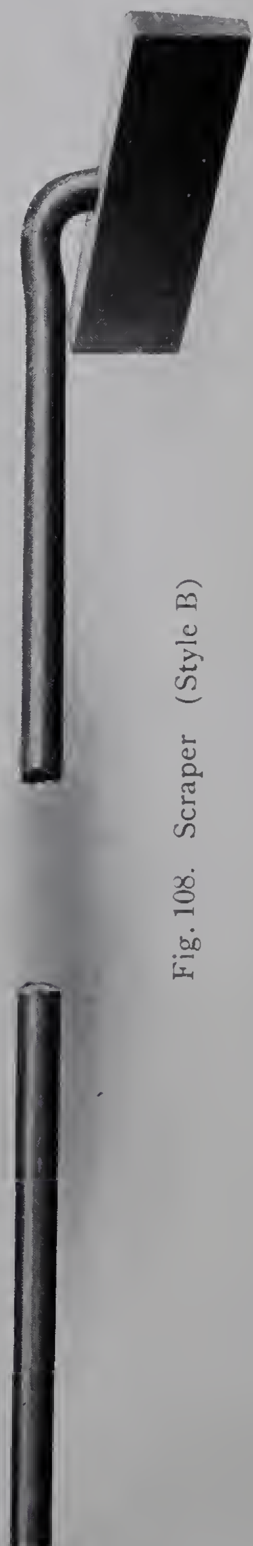


Fig. 108. Scraper (Style B)

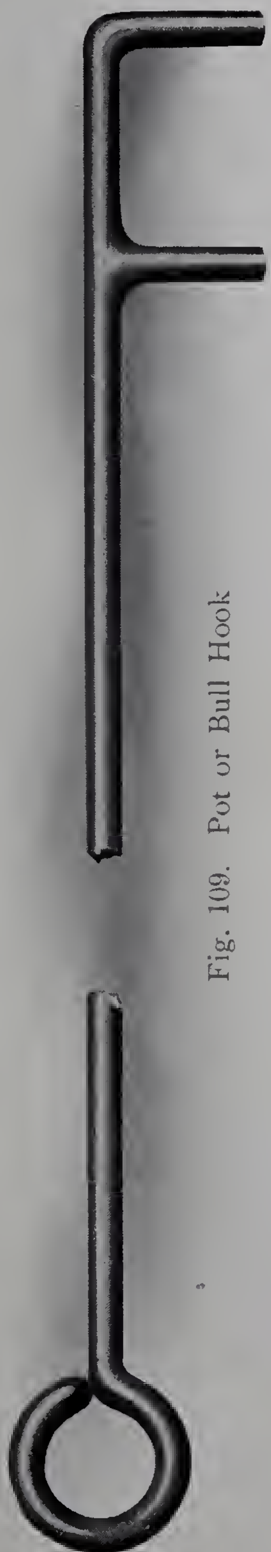


Fig. 109. Pot or Bull Hook

Fig. 110. Cropper

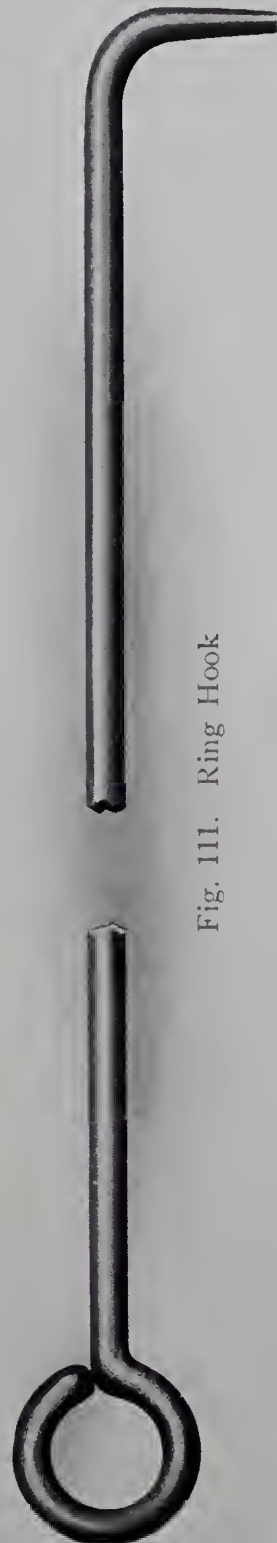


Fig. 111. Ring Hook

Fig. 112
Casting Table

Plate and Skylight Glass Factories

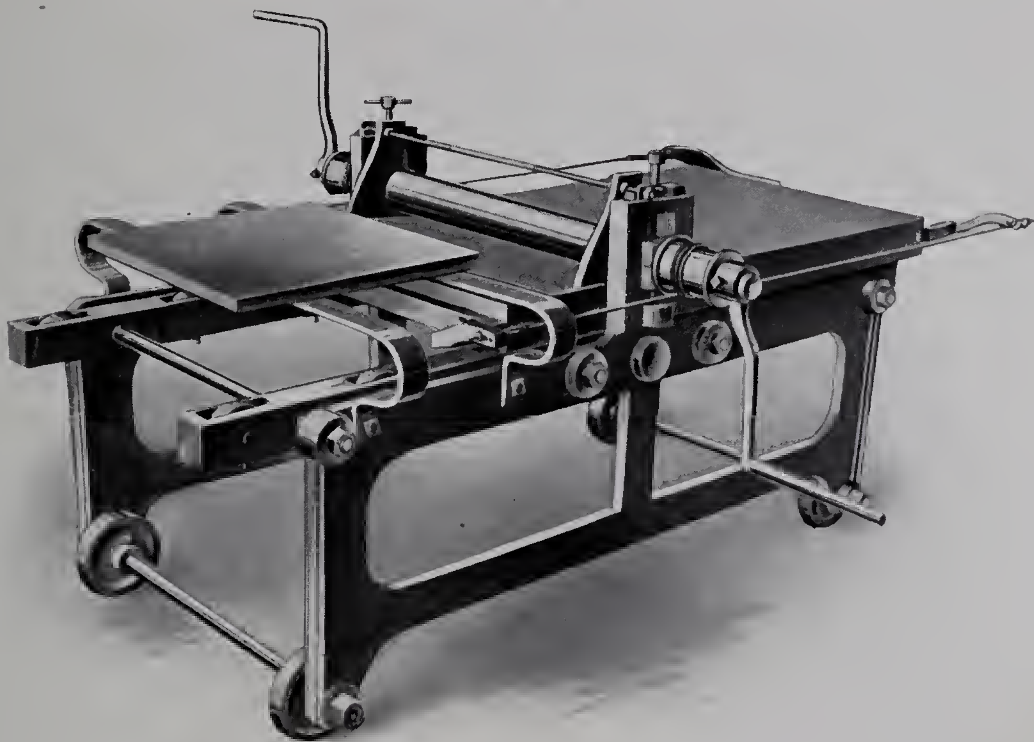


Fig. 113
Cathedral Glass Rolling Table

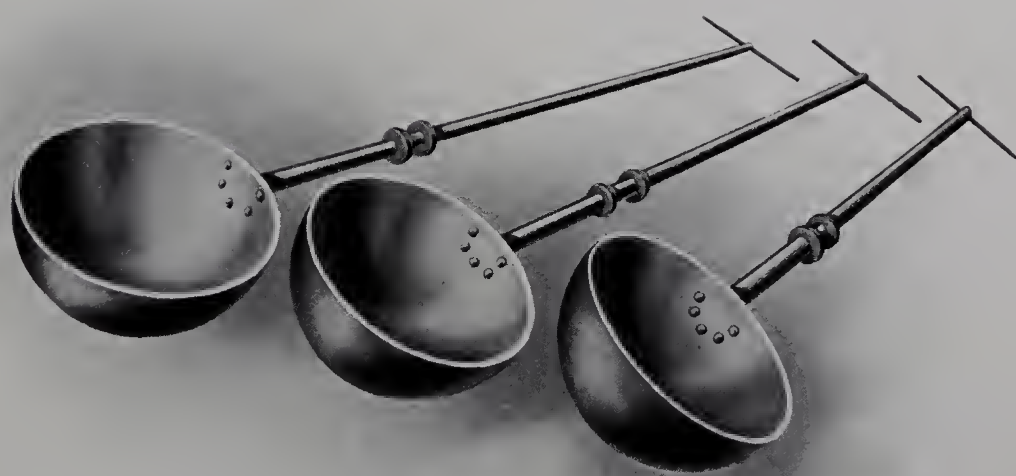
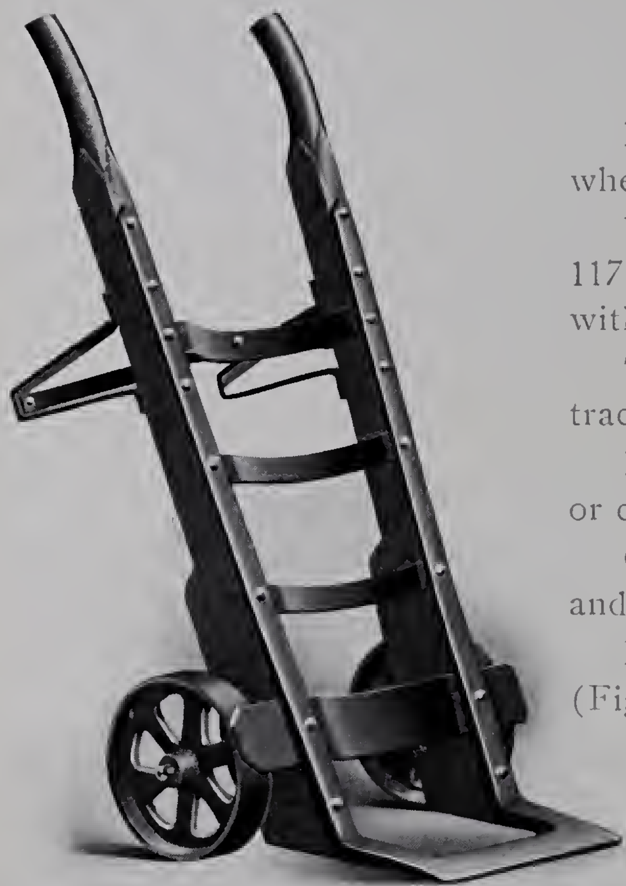


Fig. 114
Pressed Steel Ladles

Ladles (Fig. 114) of pressed steel with handles, for hand use, either circular or oval, of any size.

MISCELLANEOUS TOOLS IMPLEMENTS AND GENERAL SUPPLIES



Barrel Trucks (Fig. 115), plain wheels or rubber tires.

Warehouse Trucks (Figs. 116, 117 and 118), three or four wheels, with rubber tires or plain.

Trucks with flanged wheels for track.

Light Tee Rails, flat bar, angles or channels for tracks.

Glass Blowers' Scales (Figs. 119 and 120).

Hoisting Winches and ratchets (Fig. 52).

Fig. 115
Barrel Truck

Fig. 116
Four-Wheel Truck (Double End Rack)

Fig. 117

Four-Wheel Truck (Single End Rack)

Fig. 118

Express Truck

Pressure and Volume Blowers (Figs. 121 and 123), for steam or electric power; belt driven or direct connected to motor; with or without countershafts and bed plates.

Ventilating and Exhaust Fans.

Wind Pipes, galvanized iron.

Nozzles (Figs. 124 and 125), automatic, self-closing, or with caps, for wind pipes.

Blast Gates (Fig. 122).

Water Tanks and Steel Towers.

Water Pumps, deep well.

Oil Pumps; air compressors, storage tanks.

Oil Burners (Figs. 128 and 129), compressed air, and combination air blast and compressed air.

Monkey Wrenches, large lever and S wrenches.

Fig. 119
Bottle Scale (Round Plate)

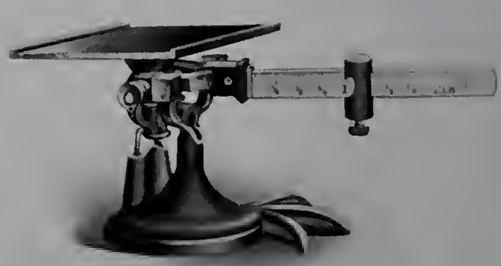


Fig. 120
Bottle Scale (Square Plate)

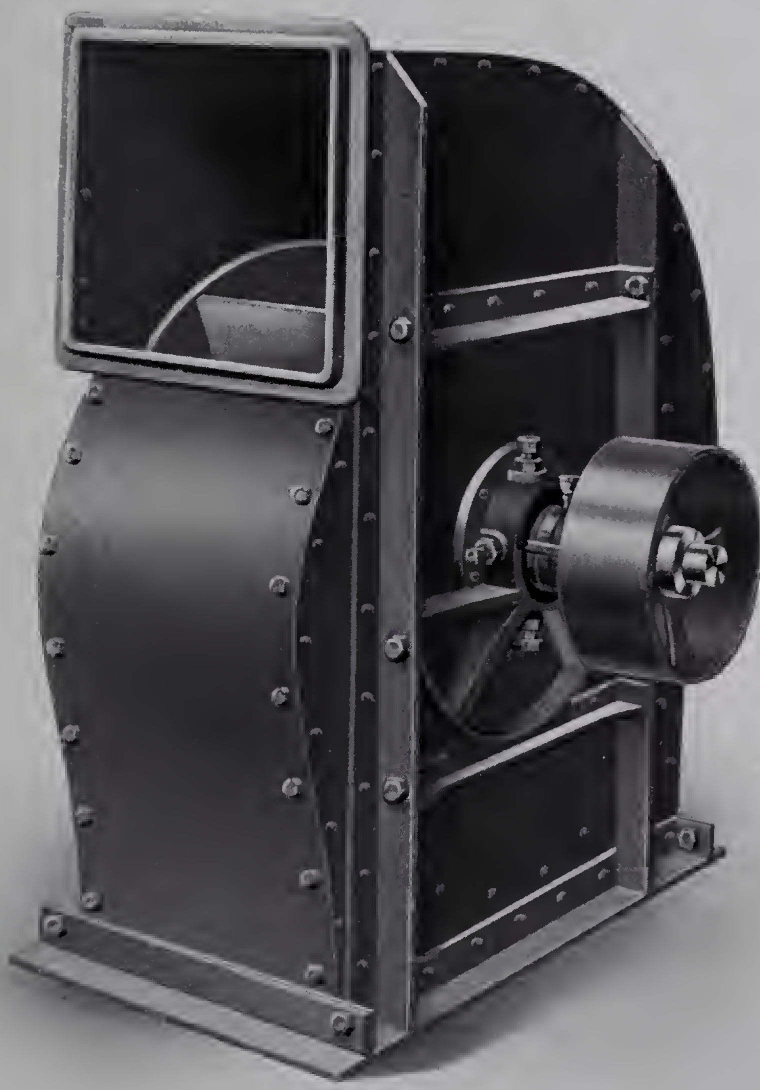


Fig. 121
Volume Blower

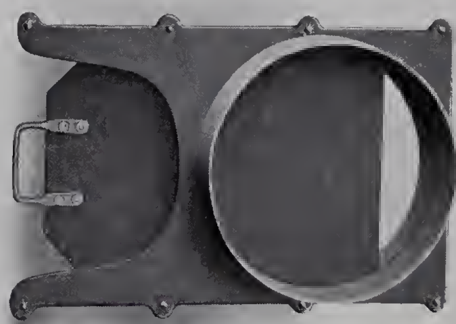


Fig. 122. Blast Gate

Fig. 123. Pressure Blower

Fig. 124
Nozzle (Closed)

Fig. 125
Nozzle (Open)

Automatic Self-Closing Nozzle for Wind Pipes

Siemens Air and Gas Reversing Valve

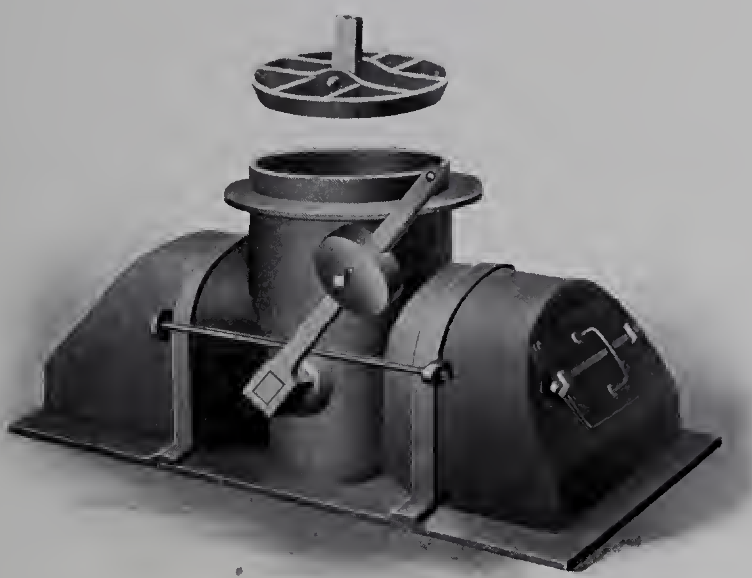


Fig. 126

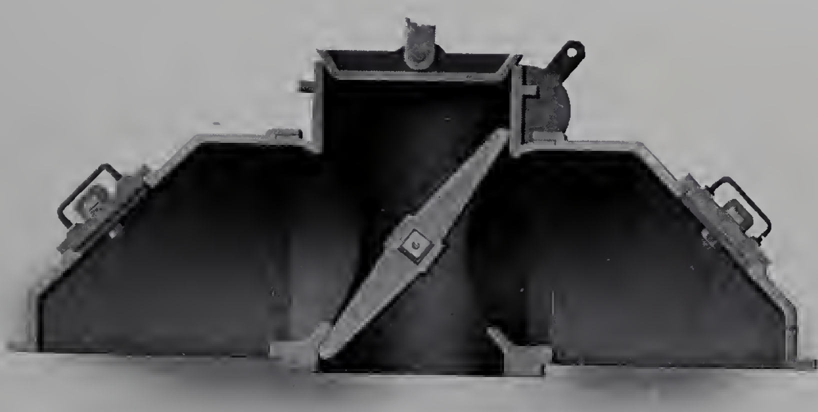


Fig. 127

Size of valve is regulated by inside diameter of top opening, which should always be given when ordering.

Air and Gas Reversing Valves

Siemens Air and Gas Reversing Valves (Figs. 126 and 127) in all sizes, 18″ to 42″ diameter, with saucers.

Square Butterfly Air Reversing Valves, in large sizes only, with lids.

Vertical Butterfly Air Reversing Valves, with corner posts, top and bottom plates and slide dampers; in sizes 24″ to 48″.

Forter Water Seal Gas Reversing Valves (Figs. 130 and 131), in all sizes, with saucers; the most perfect gas reversing valves, absolutely perfect seal, no leakage, and of greater capacity than butterfly valves.

Table of Comparative Capacities of the Forter and Siemens Air and Gas Reversing Valves

12″	Forter	Valve	equals	capacity	of	14″	Siemens	Butterfly	Valve.
14″	“	“	“	“	“	16″	“	“	“
16″	“	“	“	“	“	18″	“	“	“
18″	“	“	“	“	“	20″	“	“	“
20″	“	“	“	“	“	24″	“	“	“
22″	“	“	“	“	“	27″	“	“	“
24″	“	“	“	“	“	30″	“	“	“
27″	“	“	“	“	“	34″	“	“	“
30″	“	“	“	“	“	36″	“	“	“
32″	“	“	“	“	“	38″	“	“	“
36″	“	“	“	“	“	42″	“	“	“
42″	“	“	“	“	“	48″	“	“	“
48″	“	“	“	“	“	60″	“	“	“

Any parts of all valves furnished on request.

Fig. 128
Kirkwood Oil Burner
(Compressed Air)

Fig. 129
Kirkwood Oil Burner
(Combination Air Blast and Compressed Air)

Forter Patented Water Seal Gas Reversing Valve

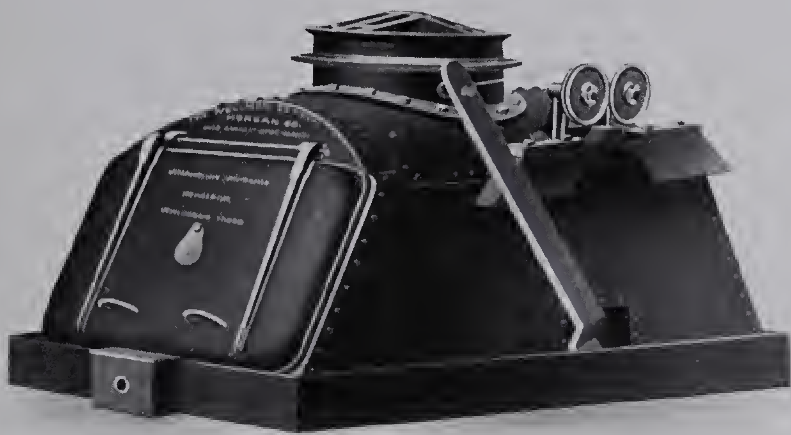


Fig. 130

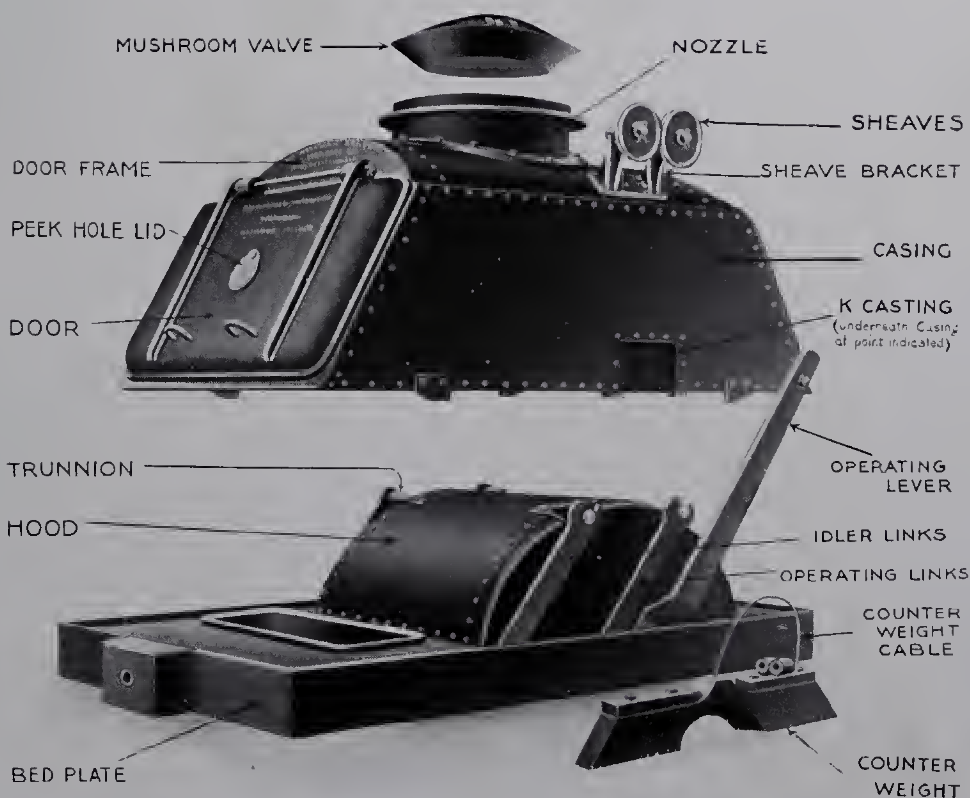


Fig. 131

Size of valve is regulated by inside diameter of nozzle or top opening which should always be given when ordering.

Batch Mixing Appliances

Secret Platform Scales (Fig. 132), with as many beams as desired; locked and sealed, cannot be tampered with.

Rotary Batch Mixers, operated by gas or steam engine, or electric motor.

Batch Elevators and Conveyors; endless chains or belts with steel buckets, boot and shafts, operated by gas or steam engine, or electric motor (Figs. 133 to 137).

Gas Engines and motors for driving batch elevators and mixers.

Steel Batch Barrows, shovels and screens.

Color Room Scales, scoops and pans.

Spiral Conveyors (Figs. 138 and 139), for handling batch; right or left-hand direction; plain or without mixing paddles.

Fig. 133
Malleable Iron Bucket with renewable steel band

Fig. 134
Malleable Iron Bucket
(a seamless bucket of large carrying capacity)

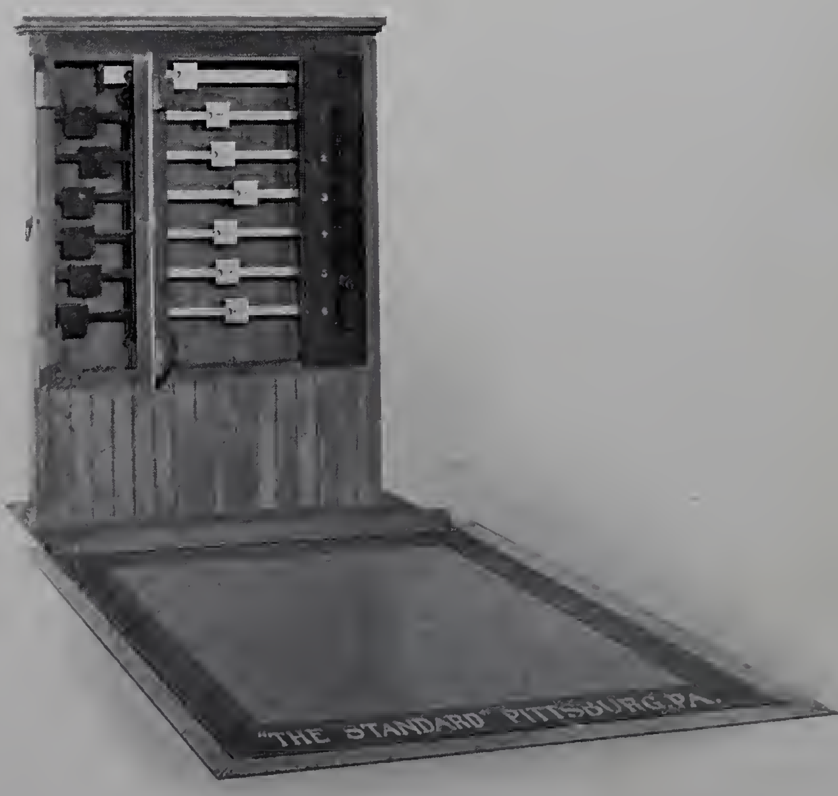


Fig. 132
Secret Scales

Fig. 135
Chain Conveyor

Fig 136
Belt Conveyor

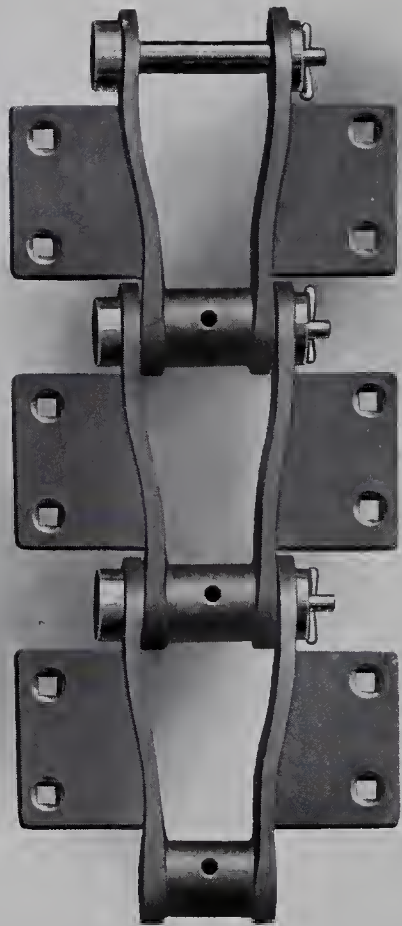


Fig. 137. Steel Bushed Chain for Conveyors

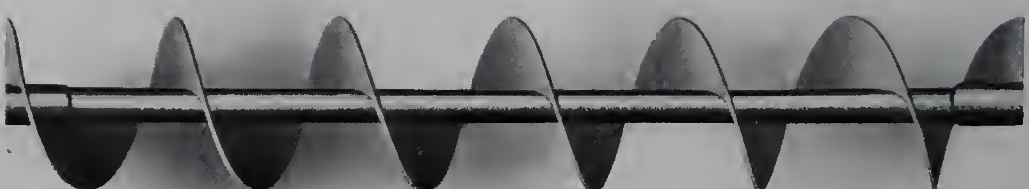


Fig. 138. Spiral Conveyor

Fig. 139. Spiral Conveyor with Mixing Paddles

Electric Safety Devices

It is well known that failure to reverse the valves regularly on regenerative furnaces is liable to result in serious damage to the furnaces and causes material fluctuations of temperature. To avoid this as far as possible, and to detect it, if it does occur, we furnish and install a **Furnaceman's Time Detector** (Fig. 140), which is connected with a clock and causes an alarm bell to ring at the end of each interval, when it is time to reverse the valves, and **which continues to ring until the valves are reversed**; it is also connected with the valve levers, which causes the clock dial to be punctured each time the valves are reversed. Any number of furnaces may be connected with the same clock and dial. They are not expensive, and furthermore make a valuable addition to your equipment.

Pyrometers

Adapted for accurately measuring the temperatures of Glass Melting Furnaces, Annealing Ovens, Lehrs, Potters' Kilns, Decorating Kilns, Staining and Burning Muffles, and for all lines of manufacture employing heat.

There has been a steadily growing demand for a scientifically accurate and reliable instrument for measuring the temperatures of all kinds of furnaces and ovens used in the mechanical arts. While the regulation of temperatures of furnaces in the different industries has depended upon the skill and judgment of the operators, more or less indifferent results have been obtained, without any positive guide for their regulation, or of any means of determining the condition or temperatures producing the best results.

Our Thermo Electric Pyrometer with platinum-rhodium couples fully meets the requirements for measuring temperatures up to 3000° Fahrenheit. It is simple in its construction, is easily installed and does not easily get out of order.

The principle involved in the construction of our Thermo Electric Pyrometer is the conversion of heat into an electric current, the strength or electromotive force of which indicating the degree of heat. The pyrometer consists of a sensitive galvanometer which indicates by the movement of a pointer, over a

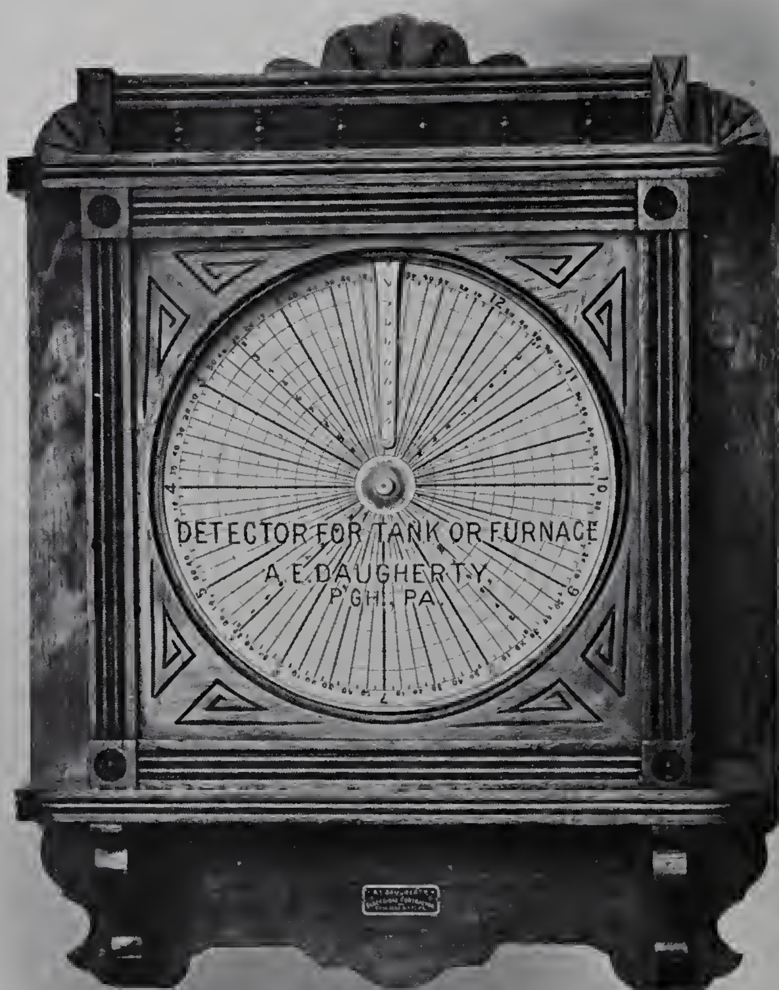


Fig. 140
Furnaceman's Time Detector

carefully calibrated scale, the current of electricity produced by heating the junction of a fine platinum and platinum-rhodium, or platinum-iridium wire, commonly termed the element.

The galvanometer and the thermo electric element constitute the complete equipment, no batteries being required.

The Thermo Electric system has many advantages over other systems, principally for its simplicity; in addition to the fact that it requires no outside batteries, adjustable resistance, or anything else that may be varied by the workman or made dependent upon their judgment. The system is one that is thoroughly accurate and capable of a high degree of precision. In its application the operator has simply to look at the instrument and read the temperature directly from the scale.

The pyrometer is extremely durable under the most severe conditions if reasonably protected.

It is obvious that this instrument is invaluable for indicating the temperature of glass melting furnaces, annealing ovens and lehrs, decorating kilns and lehrs, staining and burning muffles and a vast number of furnaces and appliances, in all lines of business where heat is employed.

Each instrument is standardized and the scale graduated accordingly. The position of the scale is such that the operator can conveniently and readily take accurate readings. Correct temperatures can be taken within one per cent.

A number of couples or stations may be connected with one pyrometer by means of a switchboard and successive readings of each station quickly made and recorded.

Automatic recording instruments are also provided when desired for recording one, two or three stations.

We furnish and install the entire equipment ready for use, or will furnish all the parts with full and complete instructions for their installation.

They are not expensive; they are accurate, durable and useful.

Low Temperature Instruments

Because of the lower cost and the increased voltage of the thermo-electric current, baser metal couples are used for temperatures below 1500° Fahrenheit. The galvanometers are calibrated for both high and low temperature couples, rendering it necessary in ordering such equipment, to state the approximate maximum temperatures of the furnaces in which the couples are to be used, or state the style of furnace, lehr or oven, which will enable us to determine the necessary equipment.

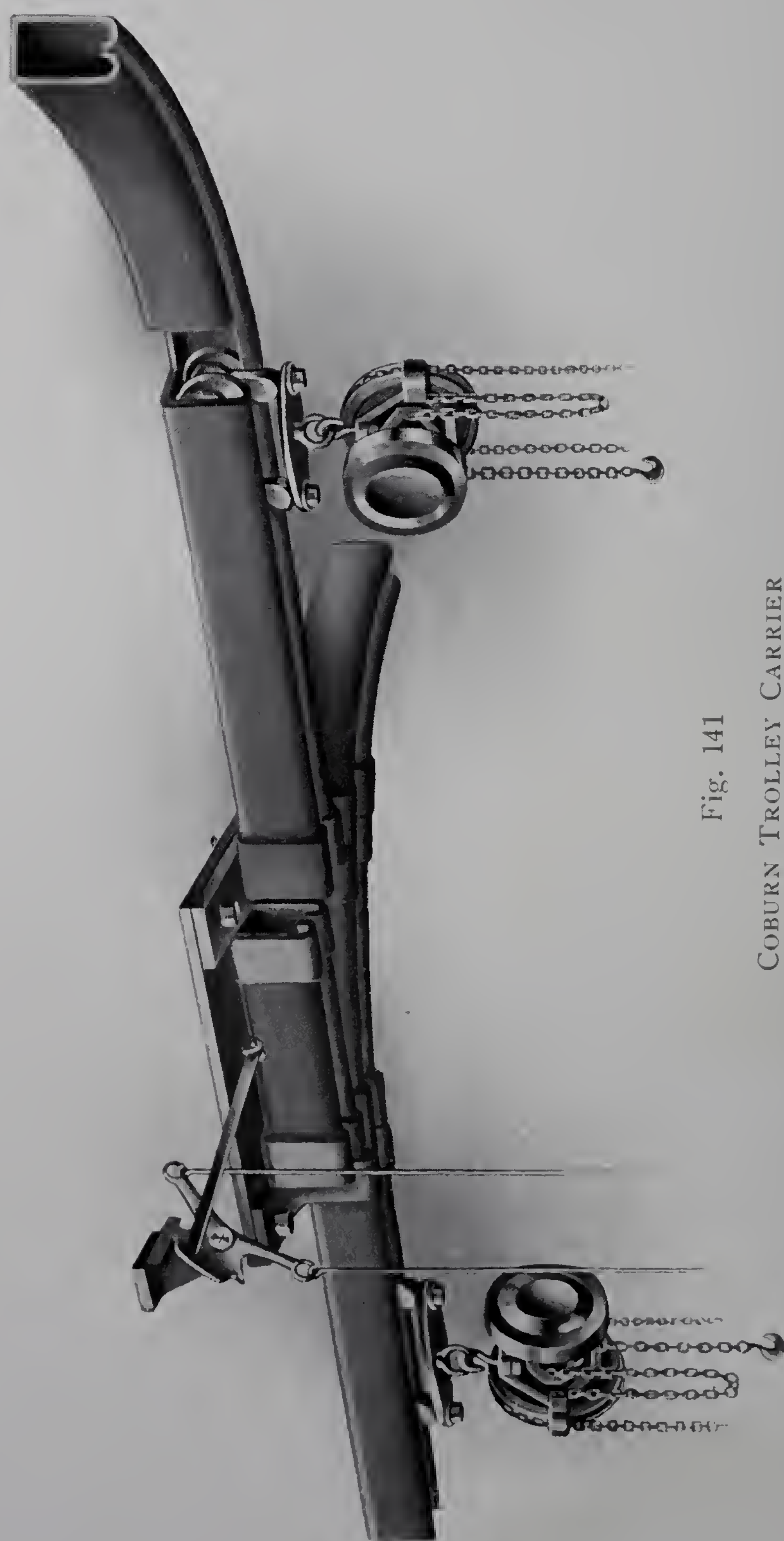


Fig. 141

Coburn Trolley Carrier

Elevation Showing Section of Track, Single Switch, Switch Throw and Trolley

Coburn Trolley Carrier

The trolley or carrier best adapted for all around service in the glass factory is the Coburn (Fig. 141), a section detail of which we illustrate on opposite page.

For handling rough plates of plate glass, lehr pans, ladles. cullet, batch and other bulky material, this type of carrier particularly lends itself. It may be used for indoor or outdoor service, as circumstances demand. This carrier is designed to stand rough, hard usage, all parts of which, with the exception of the wheels, being hand forgings, and constructed to permit moving around the smallest radius curve with ease.

The track is the most substantial of any made for the purpose, being so constructed as to make it impossible for the wheels of the carrier to get off the track.

The trolley is hung on ball bearings and very easily and readily moved.

By means of switches, curves, turntables and crosses the system can be made to meet any carrying condition required.

It is furnished in various sizes to carry any load desired.

Blacksmith and Box Shop Equipment

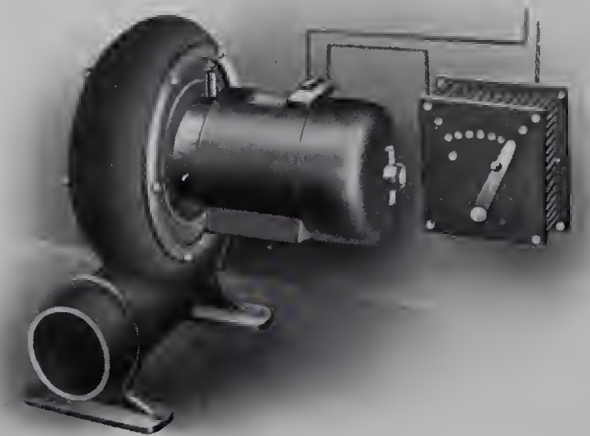


Fig. 142
Forge Blower. (Motor Driven)

Blacksmith Forges; sheet steel bases, cones and chimneys.

Anvils, hand bellows, tuyere irons, blacksmiths' sledges, hammers, chisels, mandrels, punches, files, vises and all special tools and handles.

Forge Blowers (Figs. 142 and 143), complete with motor or countershaft and pulleys.

Pressure Blowers for hand power.

Rip Saws, swinging cut-off saws, countershafts, pulleys, hangers and belting.

Box-Printing presses.

Stencils, stamps and dies.

Stencil Cutters and paper.

Coburn Trolleys (Fig. 141), track and hangers for handling heavy packages.

Box Trucks; warehouse trucks, (Figs. 116-118).

Fig. 143
Forge Blower. (Belt Driven)

Tank and Furnace Blocks, Boots, Etc.

Tank flux blocks, bottom blocks and refractory blocks.

Refractory furnace blocks for pot furnaces.

Pillar, arch and cap blocks; eye blocks.

Bench clay, mortar clay, prepared for use.

Pot-setting brick, jack brick, flue rings.

Floaters (Figs. 144 and 145), gathering rings, and boots of all sizes and patterns.

Ring shades, pot stoppers and rings.

Flattening stones, American or Belgian make.

Shade stones for flattening ovens.

Missouri Fire Clays, in lump or ground in barrels.

Producer hopper and poke-hole blocks.

Fire Brick of all grades, all standard shapes.

Silica Brick, both 12″ and 9″ series of shapes.

Corundite in all 9″ brick shapes. Special brick shapes. Blocks of special design for tank and furnace construction. Prepared for use in mending furnaces, lining pots and for special purposes where other material has failed.

Floaters for Glass Melting Tanks

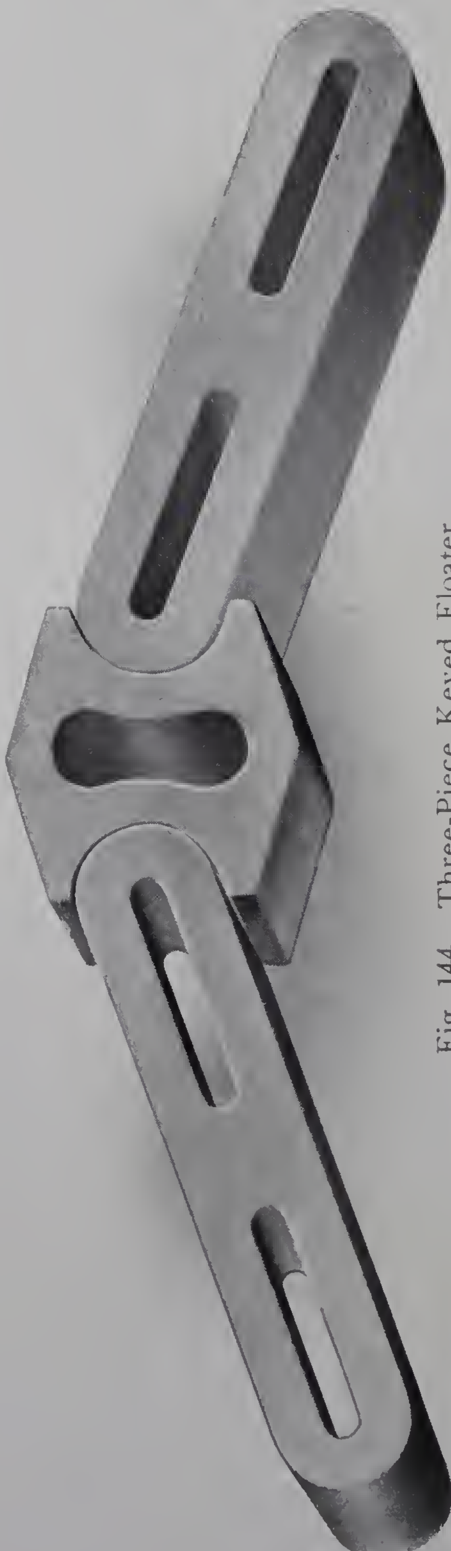


Fig. 144. Three-Piece Keyed Floater

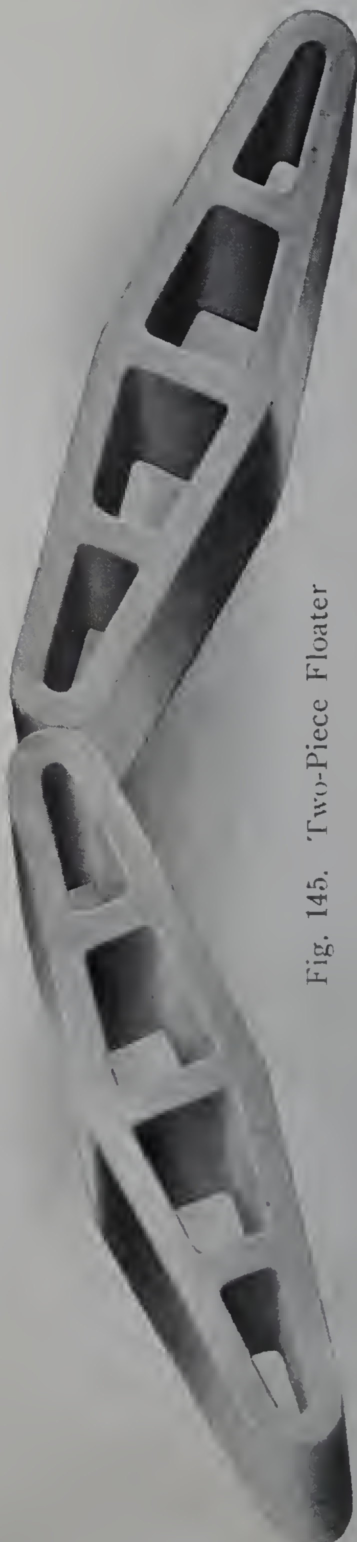


Fig. 145. Two-Piece Floater

Fig. 146. "E" Block—Top of Ports
(Dixon Pattern)
"X" Dimension = 24″ for 24″ Flues
"X" " = 16″ " 16″ "

Fig. 147. "Dixon" Burner Block

Fig. 148. Skew Block for Tunnels in Dixon Double Division Wall
(Dixon Pattern)
"X" Dimension = 36″, 42″ or 48″

Fig. 149. Doghouse Mantle Block
(Dixon Pattern)

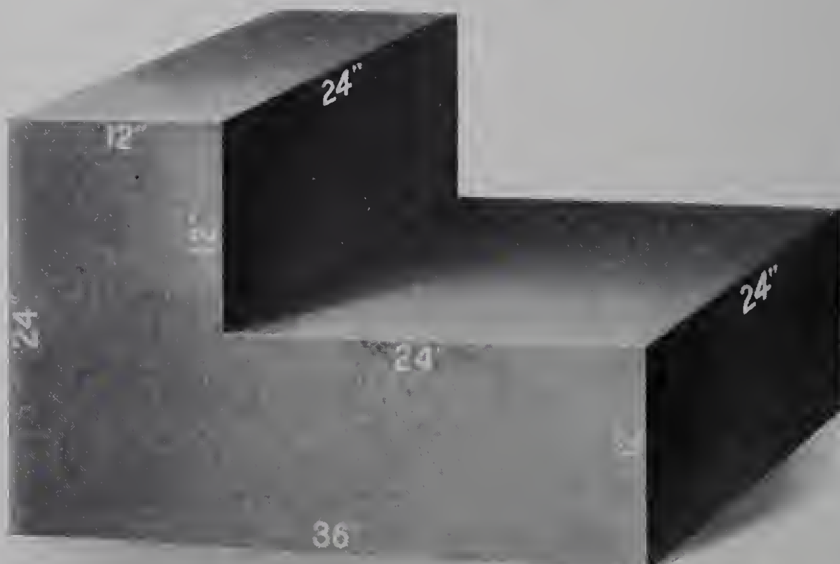


Fig. 150. Doghouse Corner or "L" Block
(Dixon Pattern)
Made in 18″ and 24″ sizes

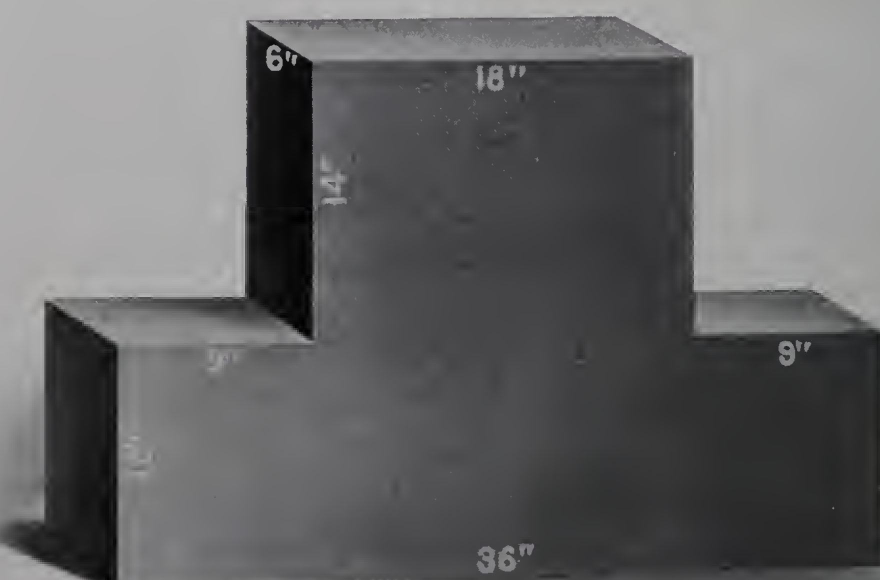


Fig. 151. "11" Block—Bottom of Filling Hole
(Dixon Pattern)

Fig. 152. "C" Block—Covering Division Wall
(Dixon Pattern)
"X" Dimension = 12″, 18″ or 24″ Air Space

Fig. 153. Tank-wall Block over Spout
(Dixon Pattern)

Fig. 154. "B" Block—Top and Bottom of Dixon Square Spout
(Dixon Pattern)
"X" Dimension = 12″, 18″ or 24″

Fig. 155. No. 1 Tank-wall Tuckstone
(Dixon Pattern)

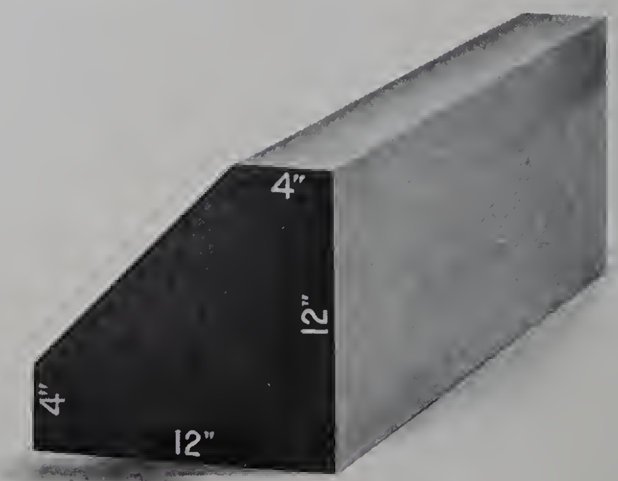


Fig. 156. No. 2 Tank-wall Tuckstone
(Dixon Pattern)

Fig. 157. No. 3 Tank-wall Tuckstone
(Dixon Pattern)

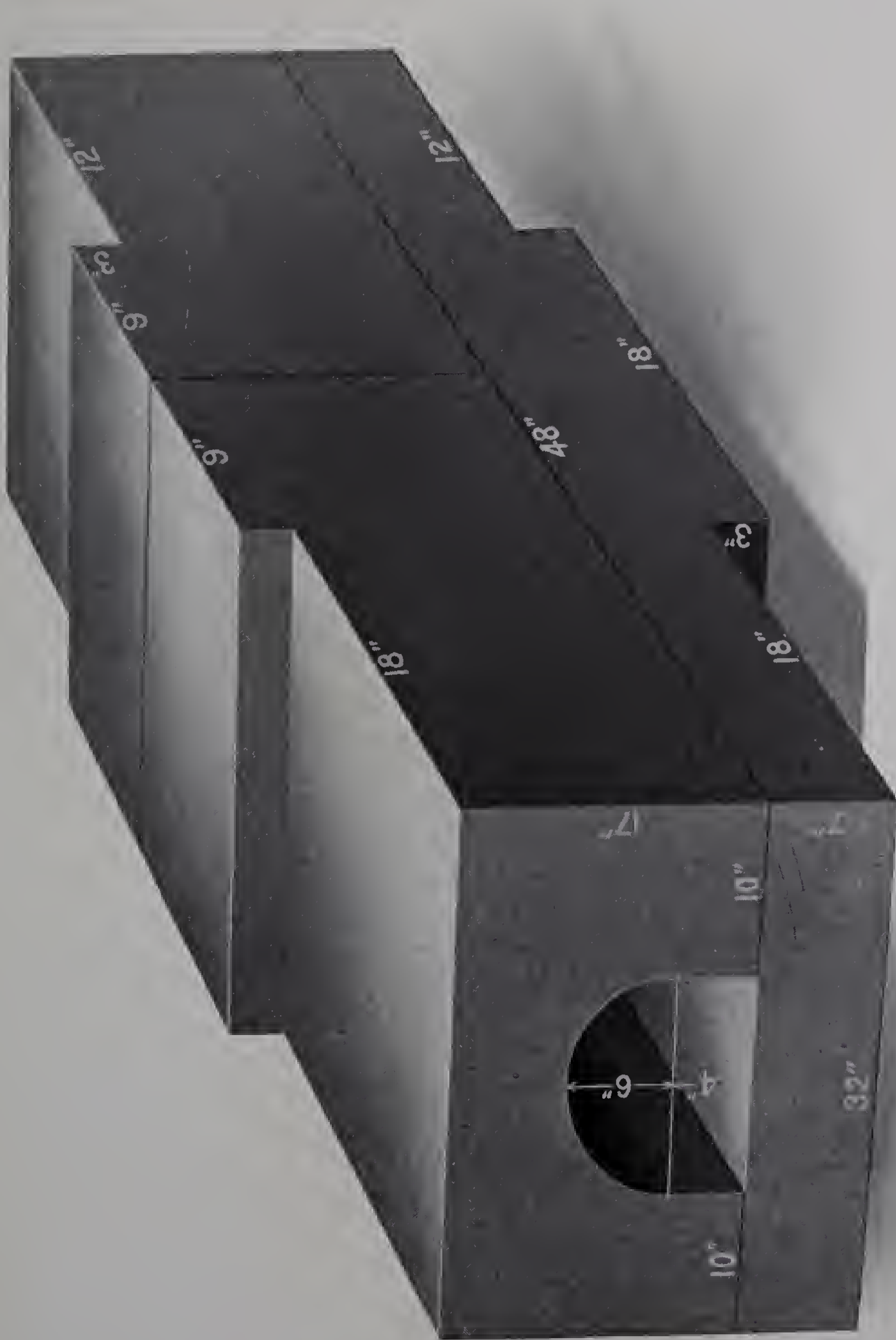


Fig. 158. "Dixon" Spout, Semi-circular or Square

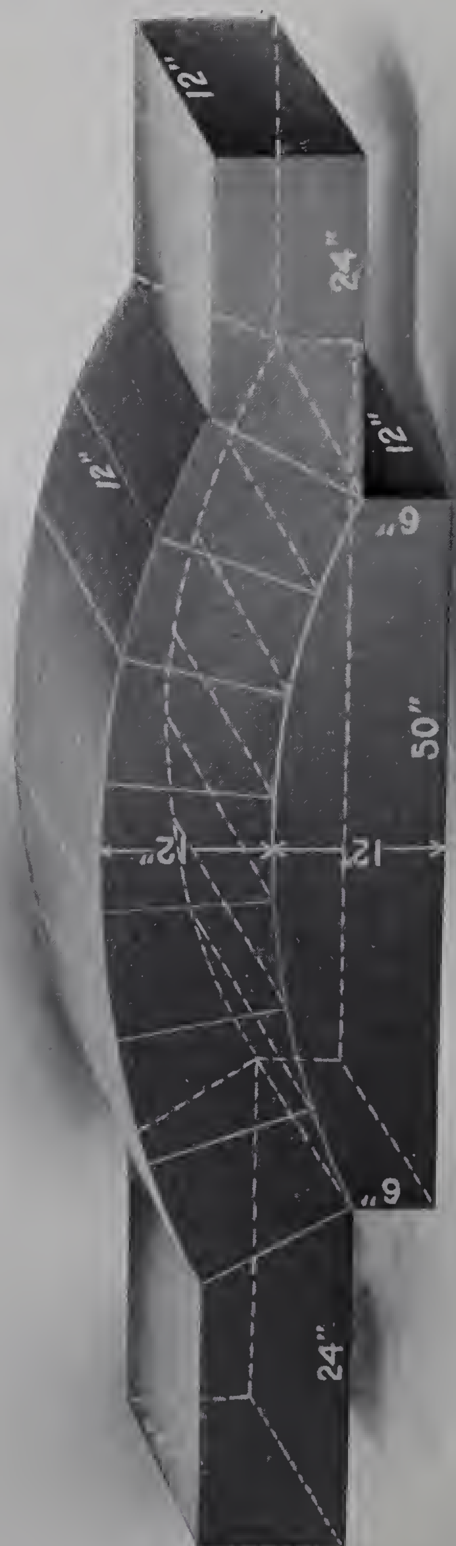


Fig. 159. Doghouse Arch, Skew and Mantle Blocks
(Dixon Pattern)

Gatherers' Boots

THESE boots are made of various shapes and sizes and may be ordered as desired. The size of hood or depth may be changed to suit conditions. The deeper the boot, the stiffer the glass will be. The deep boots are used for gatherers of large ware, and are provided with openings above the glass for regulating the temperature within the boot. Others are very shallow, and are only used to skim the surface of the glass and to prevent sting-out. A deep boot may be sawed off to any depth desired. They can be placed in the furnace while it is in operation, by previously heating them to nearly the temperature of the furnace.

We illustrate on the following pages a number of the stock sizes in common use.

Dixon Boot

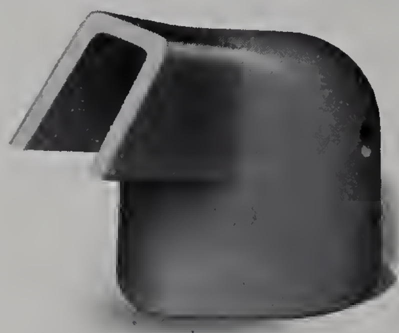


Fig. 160

Fig. 161

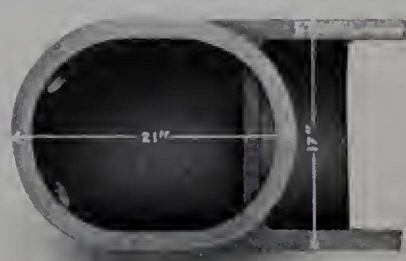


Fig. 162

Star Boot

Fig. 163

Fig. 164

Fig. 165

Circular Boot

Fig. 166

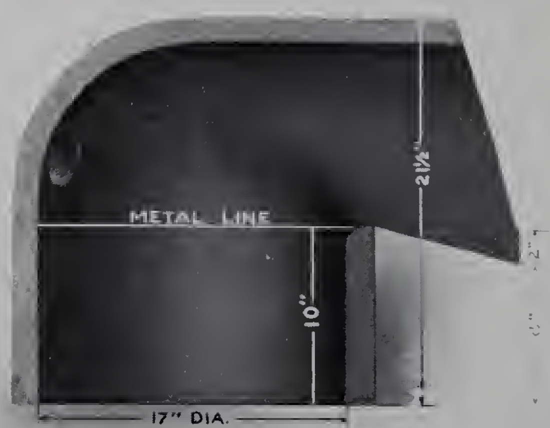


Fig. 167

Fig. 168

Diamond Boot

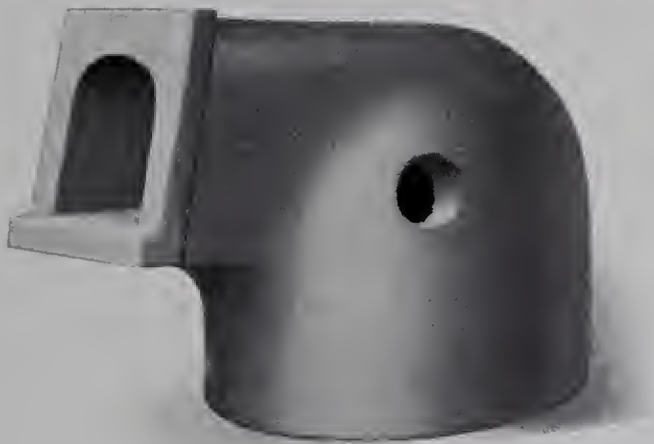


Fig. 169

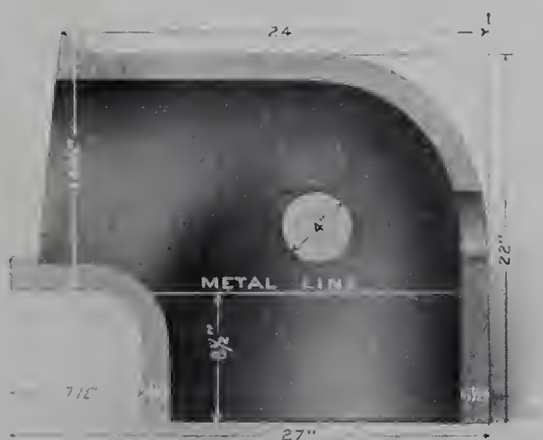


Fig. 170

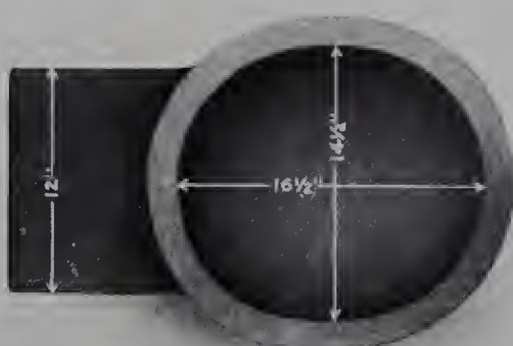


Fig. 171

McLaughlin Boot

Fig. 172

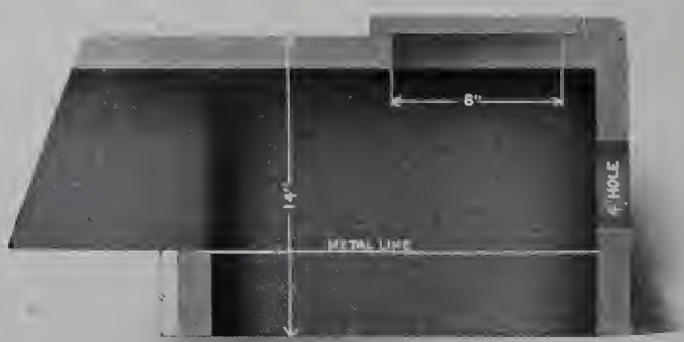


Fig. 173

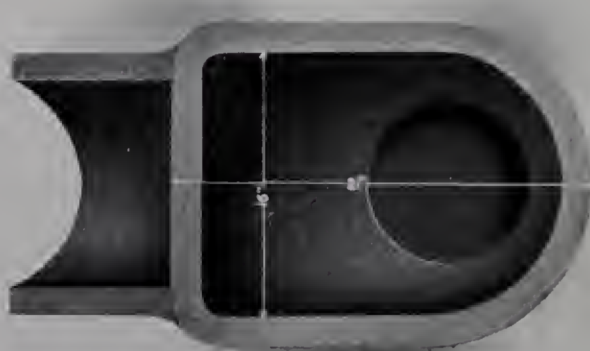


Fig. 174

Carolina Boot

Fig. 175

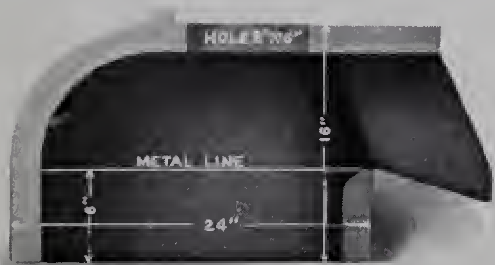


Fig. 176

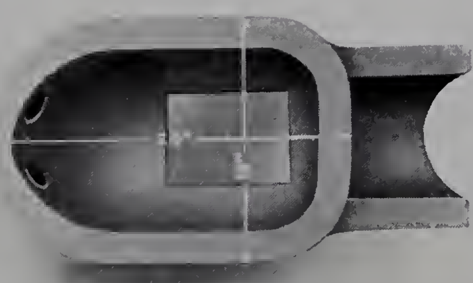


Fig. 177

Fox Boot

Fig. 178

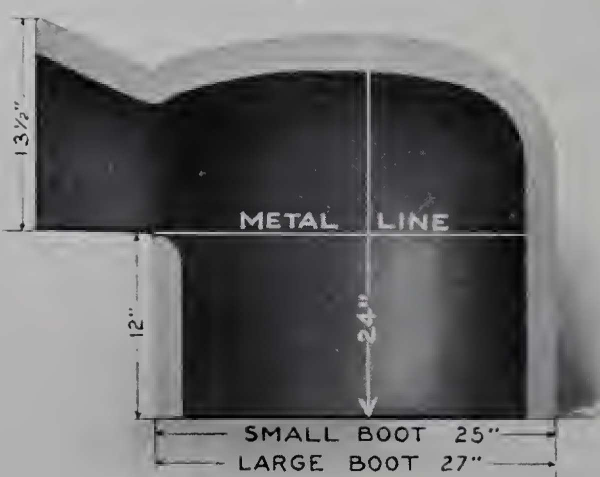


Fig. 179

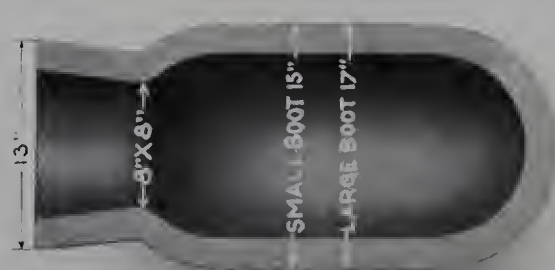


Fig. 180

Humphrey Boot

Fig. 181

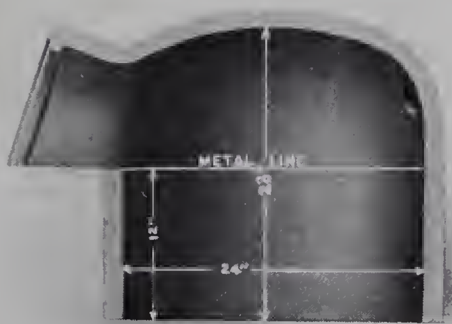


Fig. 182

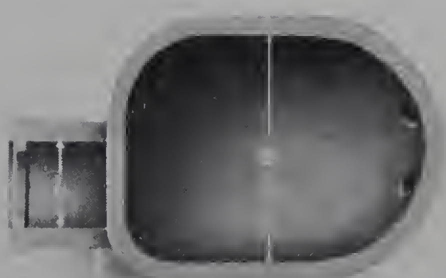


Fig. 183

McKee Boot

Fig. 184

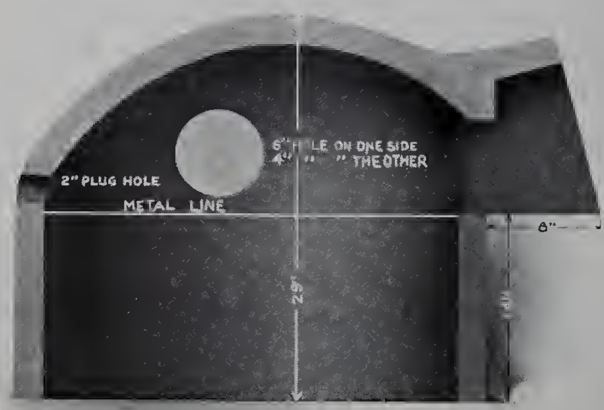


Fig. 185

Fig. 186

Whitney Boot

Fig. 187

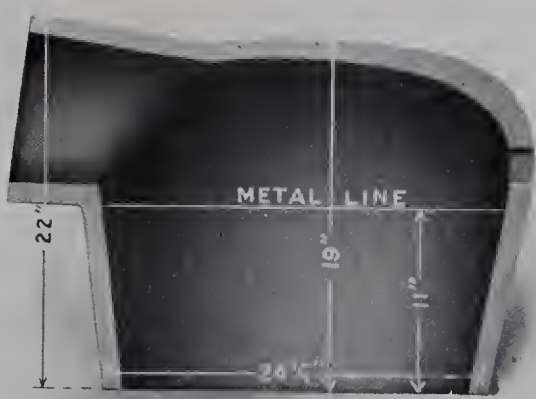


Fig. 188

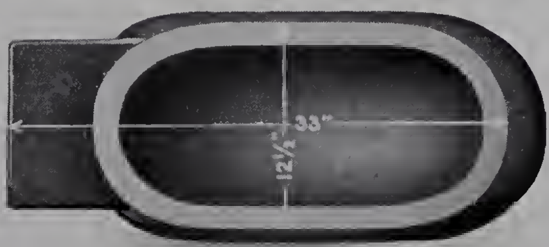


Fig. 189

Silica and Fire Clay Brick

Nine Inch Series

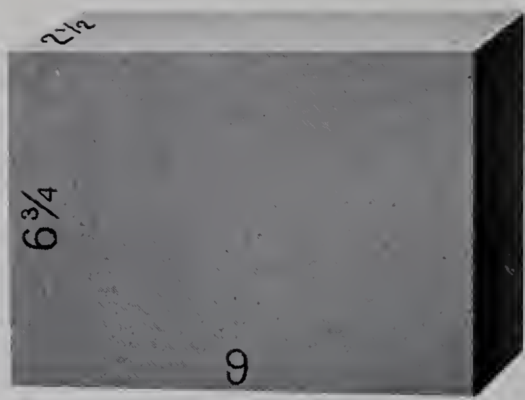


Fig. 190

Large Nine Inch

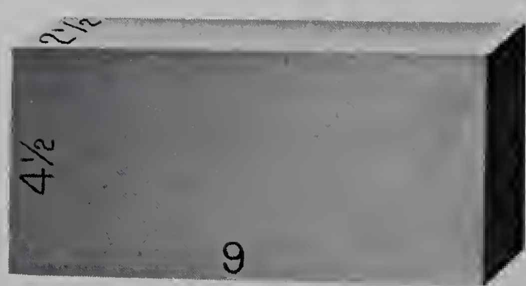


Fig. 191

Regular Nine Inch

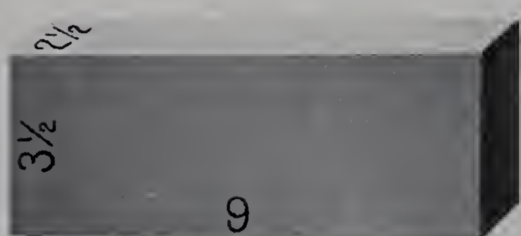


Fig. 192

Small Nine Inch

Fig. 193

No. 1 Split

No. 2 Split

Fig. 194

Soap

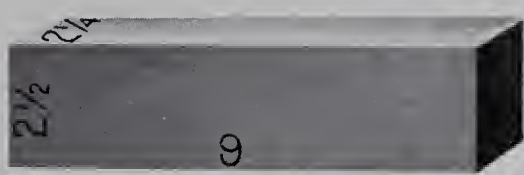


Fig. 195

No. 1 Wedge
5′-0″ diameter inside
102 brick to the circle

Fig. 196

No. 2 Wedge
2′-6″ diameter inside
63 brick to the circle

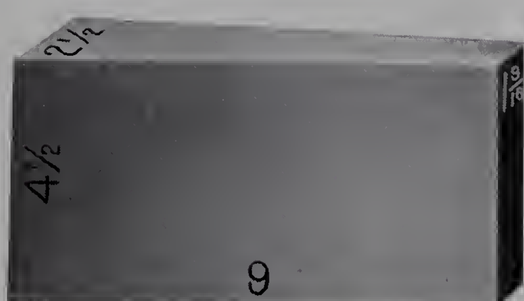


Fig. 197

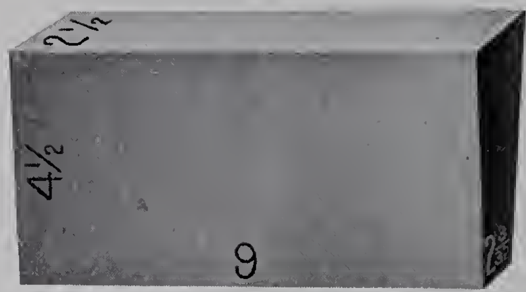


Fig. 198

No. 1 Arch
5′-0″ diameter inside
72 brick to the circle

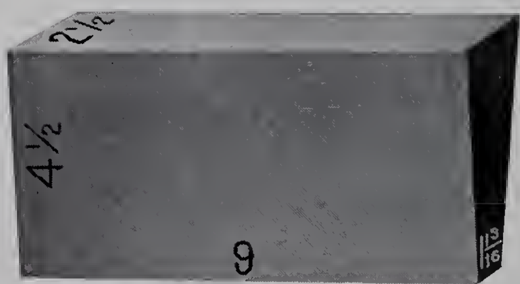


Fig. 199

No. 2 Arch
2′-0″ diameter inside
42 brick to the circle

Fig. 200

No. 1 Key
12′-0″ diameter inside
112 brick to the circle

Fig. 201

No. 2 Key
6′-0″ diameter inside
65 brick to the circle

No. 3 Key
3′–0″ diameter inside
41 brick to the circle

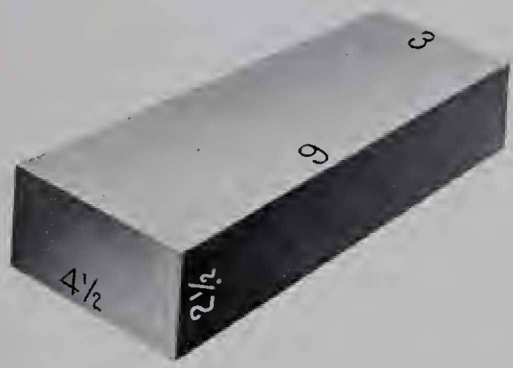


Fig. 202

No. 4 Key
1′–10″ diameter inside
26 brick to the circle

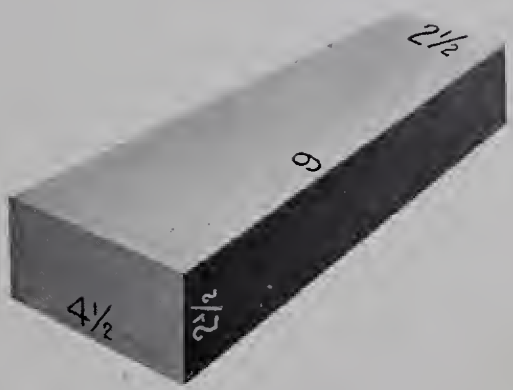


Fig. 203

No. 1 (End) Skew

Fig. 204

No. 2 (Side) Skew

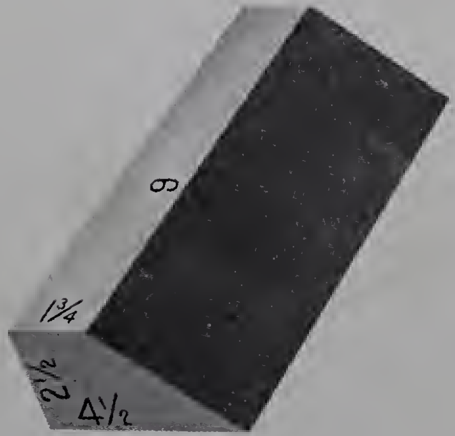
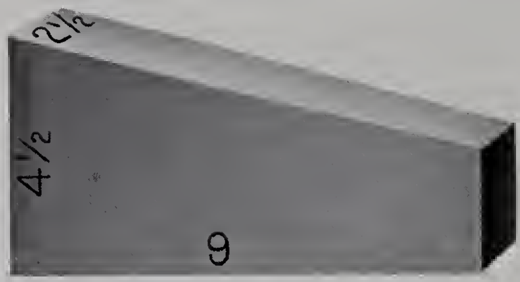


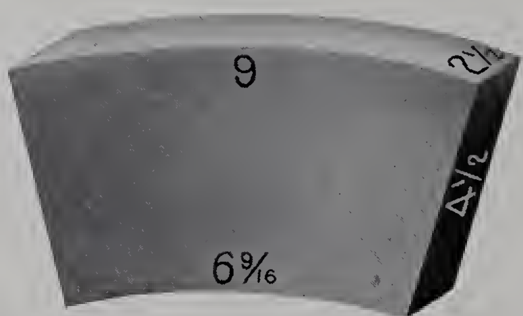
Fig. 205



No. 3 (Edge) Skew

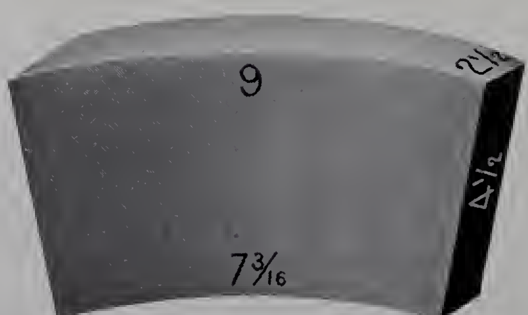
Fig. 206

Miscellaneous Fire Clay Shapes



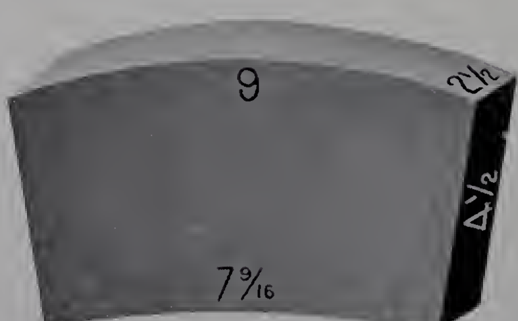
No. 1 Circle
33″ diameter outside
24″ diameter inside
11 brick to the circle

Fig. 207



No. 2 Circle
45″ diameter outside
36″ diameter inside
14 brick to the circle

Fig. 208



No. 3 Circle
57″ diameter outside
48″ diameter inside
20 brick to the circle

Fig. 209

No. 4 Circle
69″ diameter outside
60″ diameter inside
23 brick to the circle

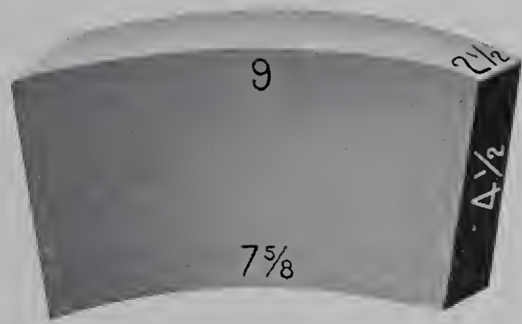


Fig. 210

No. 1 Cupola
42″ diameter outside
30″ diameter inside
15 brick to the circle

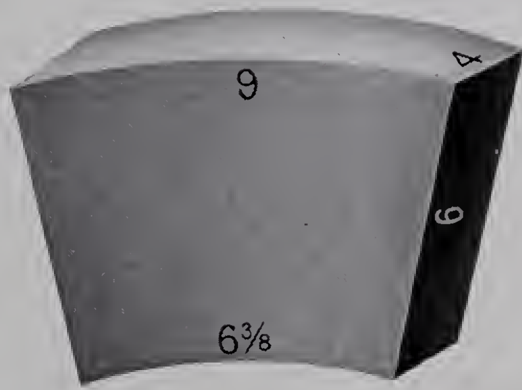


Fig. 211

No. 2 Cupola
48″ diameter outside
36″ diameter inside
17 brick to the circle

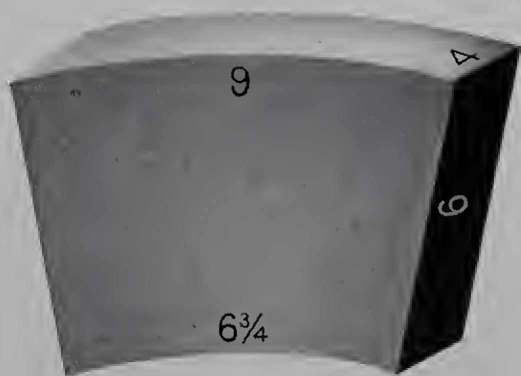


Fig. 212

No. 3 Cupola
60″ diameter outside
48″ diameter inside
21 brick to the circle

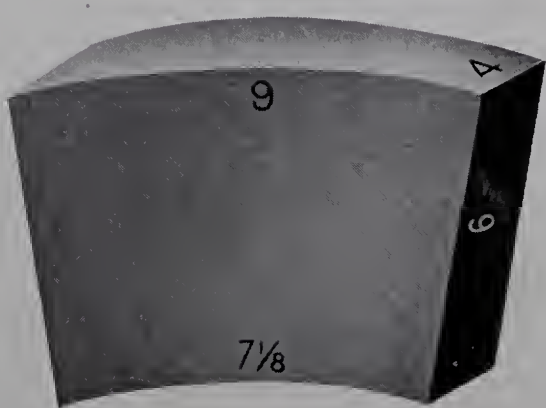


Fig. 213

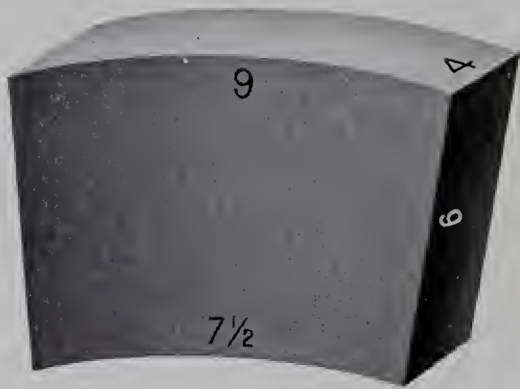


Fig. 214

No. 4 Cupola
72″ diameter outside
60″ diameter inside
25 brick to the circle

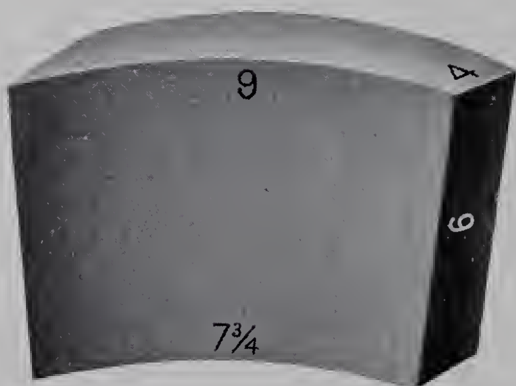


Fig. 215

No. 5 Cupola
84″ diameter outside
72″ diameter inside
29 brick to the circle

13″ Series

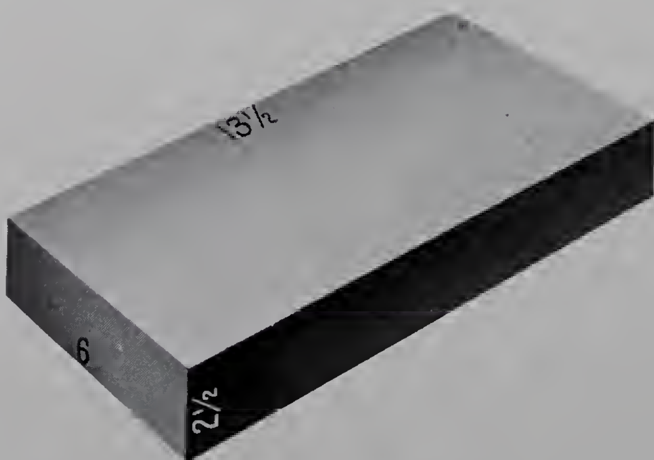


Fig. 216

13½″ Straight

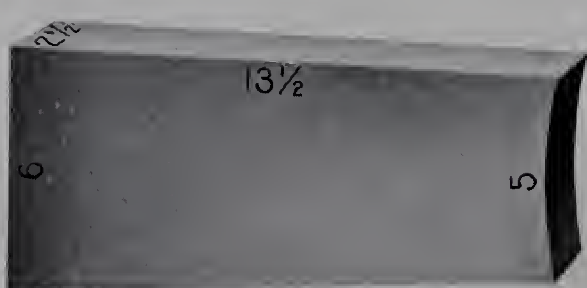
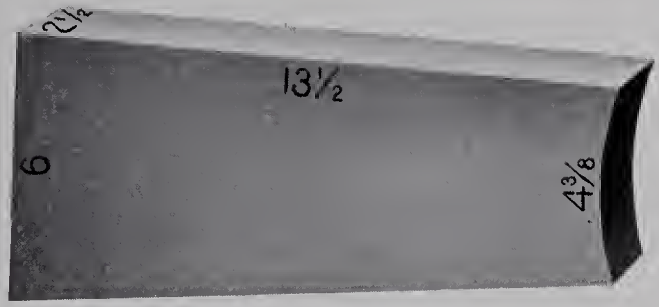


Fig. 217

13½″ No. 2 Key
12′-0″ diameter inside
90 brick to the circle



13½″ No. 4 Key
6′-0″ diameter inside
52 brick to the circle

Fig. 218

Regenerator Tile

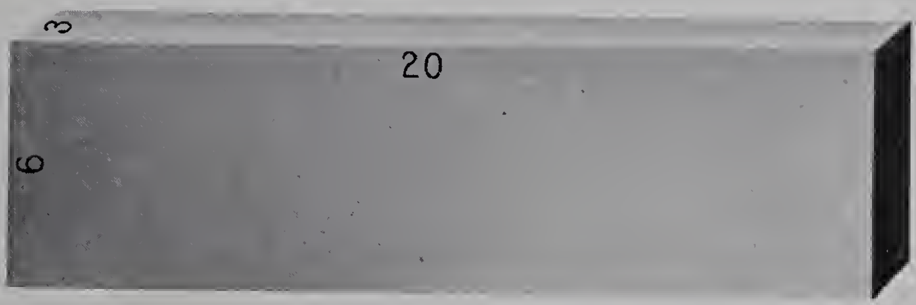


Fig. 219

The following sizes kept in stock:

16 x 6 x 3	20 x 6 x 3	24 x 6 x 3
18 x 6 x 3	21 x 6 x 3	24 x 9 x 3
19 x 6 x 3	22 x 6 x 3	26 x 9 x 3

All other sizes made to order

Silica Shapes
Twelve Inch Series

12″ Straight

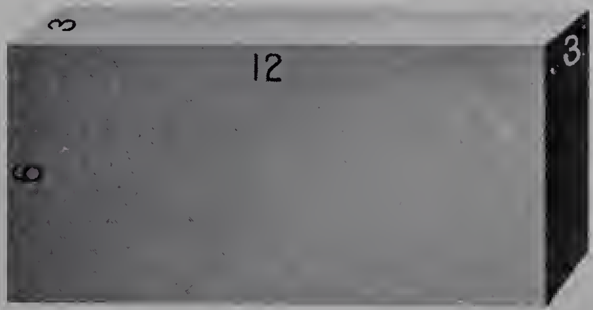


Fig. 220

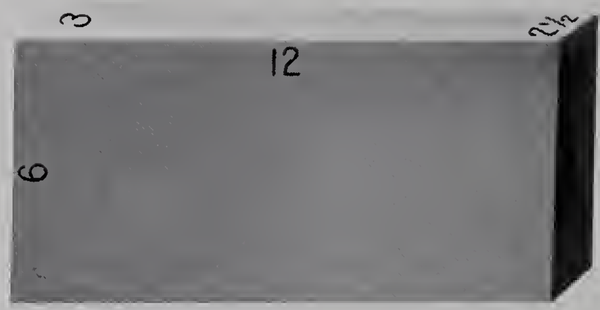


Fig. 221

12″ No. 1 Wedge

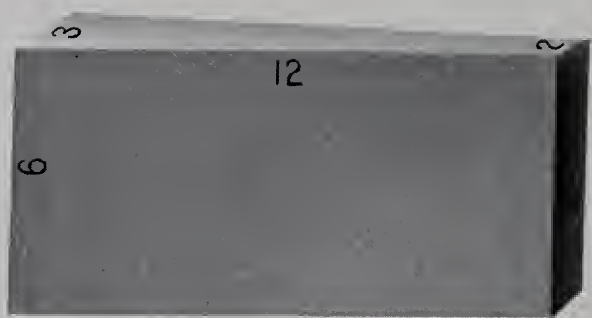


Fig. 222

12″ No. 2 Wedge

Fig. 223

12″ Side Arch

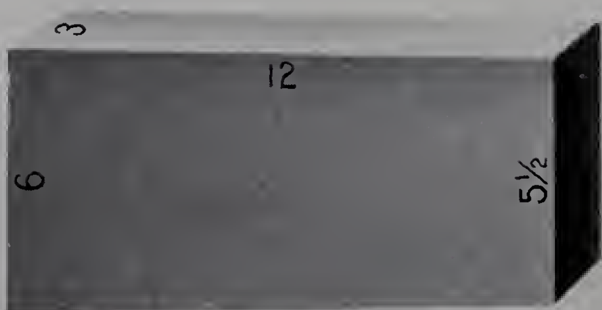


Fig. 224

12″ No. 1 Key

12″ No. 2 Key

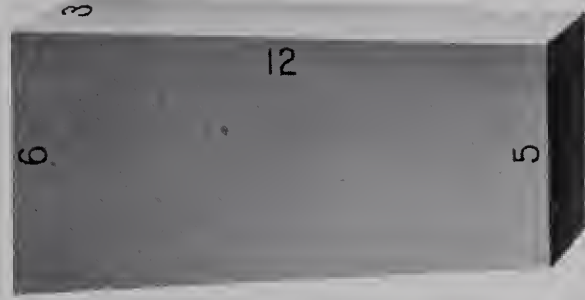


Fig. 225

12″ Soap

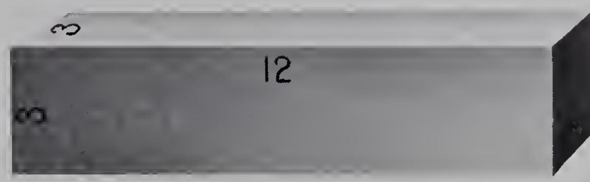


Fig. 226

12″ Large Square

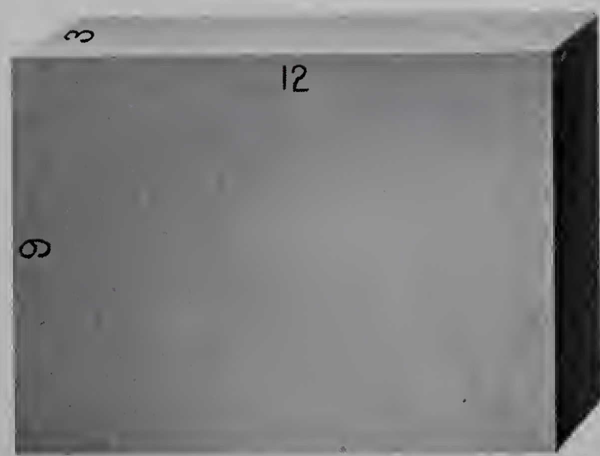


Fig. 227

12″ Large, No. 1 Wedge

Fig. 228

Muffle Tile

All 16″ Lengths

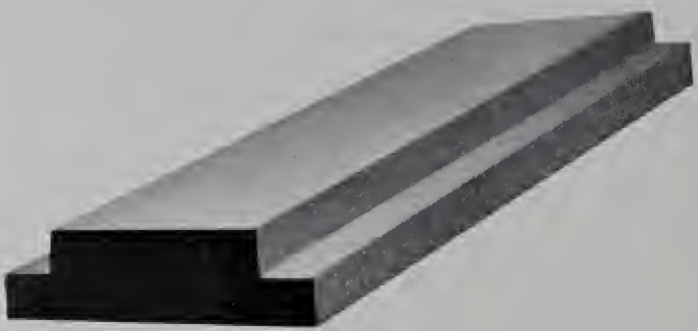


Fig. 229

D. F. Bottom Tile

Fig. 230

Bottom Side Tile

Fig. 231
Side Tile

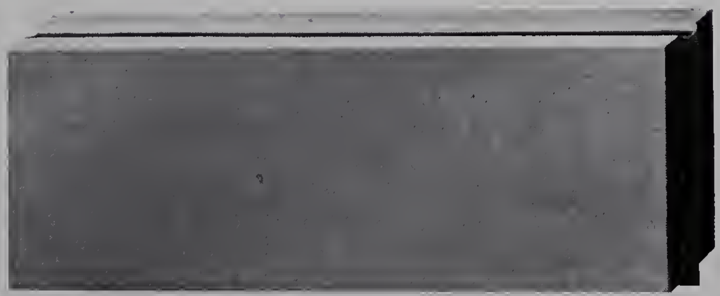


Fig. 232
Roof Tile

SUPPLEMENT OF

TABLES AND USEFUL INFORMATION

Supplement of Valuable Tables and Useful Information

IN presenting this addition to our general catalogue, we have endeavored to furnish such important tables and general information as would be of assistance to our friends in the glass industry.

The matter herein added has been carefully selected, condensed and simplified, useless repetition and technical phraseology have been, as far as possible, avoided.

The best references available have been investigated, and where so many authorities have been consulted, the combination of all in the condensed scope of this work precludes special reference to most of them.

Trusting that our efforts will be of some assistance to you in your every-day calculations, we subscribe ourselves,

Very sincerely yours,

H. L. DIXON COMPANY

Brick Work

General Information

A standard fire brick (9 inches straight) weighs 7 pounds.

A standard silica brick weighs 6.2 pounds.

A standard magnesia brick weighs 9 pounds.

A standard chrome brick weighs 10 pounds.

A silica brick expands ⅛ inch per foot when heated to 1,500° F.

In the process of manufacture, clay brick will expand or shrink, dependent upon the proportion of silica to alumina contained in the brick; but most fire clay brick contain alumina sufficient to show some shrinkage.

Under high temperatures fire brick will expand slightly but silica brick much more so. Therefore be careful of furnace stays.

Good brickwork depends much on the following points:

Use of good fire clay (equal in refractoriness to the brick itself) applied very thin, preferably dipped and rubbed close.

Silica brick, when necessary, should be laid in silica cement and with the smallest joint possible.

All fire brick should be kept in a dry place, moisture, especially in cold weather, will greatly injure any brick.

New brickwork should be dried out slowly and thoroughly by air, when time will permit. When the fires are lighted, it should be warmed up slowly to expel moisture, before applying severe heat. This is especially true of the Benches.

Old brickwork may be heated more rapidly, unless during the shut-down it has absorbed moisture, in which case gradual heating is advisable.

The refractoriness of silica brick is greatly decreased by sudden heating.

Furnaces should be cooled slowly.

Cold air after extreme heat is the hardest test on good fire brick.

Lighter burned fire clay brick in roofs will usually give better service than hard burned brick.

The following notes will be found useful in approximating on fire brickwork:

Brickwork is generally measured by 1,000 brick laid in the wall. In consequence of variations in size of brick, no rule for volume of laid brick can be exact. The following scale, however, is a fair average:

7	Common	brick	to a	super.	ft.	4-inch	wall.	
14	"	"	"	"	"	9	"	"
21	"	"	"	"	"	13	"	"
28	"	"	"	"	"	18	"	"
35	"	"	"	"	"	22	"	"

One cubic foot of wall requires 17 9-inch brick; one cubic yard requires 460. Where wedges, arches and keys are used, add 10 per cent in estimating the number required.

Corners are not measured twice as in stonework. Openings over 2 feet square are deducted. Arches are counted from the spring. Fancy work counted 1½ brick as 1. Pillars are measured on their face only.

One yard of paving requires 36 stock brick, of size 8¾ x 4¼ x 2¾ laid flat, or 52 on edge; and 35 paving brick laid flat, or 62 on edge.

One cubic foot of red brickwork, with common mortar, weighs from 100 to 110 pounds.

1 cubic foot fire clay brickwork weighs 150 pounds.

1 cubic foot silica brickwork weighs 130 pounds.

1,000 brick closely stacked occupies 56 cubic feet.

1,000 brick loosely stacked occupies 72 cubic feet.

Shipments

Carload shipments usually make better time in transit from shipping point to destination than less than carload.

The minimum carload of clay or brick is 40,000 pounds.

Clay for shipment by boat or less than carload by rail must be sacked or barreled.

Cement, Lime, Mortar, Etc.

Lime mortar consists of one part of lime and not more than four parts of sand.

All lime used for mortar should be thoroughly burnt, of good quality and properly slaked and run off before it is mixed with sand.

Lime will absorb one-fourth of its own weight of water before it is thoroughly slaked and will expand to two or three times its lump size.

In mixing concrete or mortar the following sizes and capacities of boxes, bins, etc., may be found useful:

Length	Breadth	Depth	Capacity
8 feet 0 inches	4 feet 0 inches	2 feet 0 inches	16 bbls.
5 " 0 "	3 " 0 "	2 " 0 "	6 "
24 "	16 "	28 "	1 "
26 "	15 "	8 "	¼ "

One ton of ground fire clay should be sufficient to lay 3,000 ordinary fire brick.

Thirteen bushels of mortar will lay 1,000 brick.

From 400 to 600 pounds of fire clay or silica cement is enough to lay up 1,000 brick. Fine ground fire clay should be used for laying up fire clay brick and silica cement for silica brick.

A cubic yard of mortar requires one cubic yard of sand and nine bushels of lime, and will fill 30 hods.

Twenty-seven cubic feet or 1 cubic yard is equal to a single load of sand, also equal to 21 bushels.

Earth and clay increases in bulk about ¼ when dug; sand and gravel 1/10.

Miscellaneous Weights, Etc.

Cement (Hydraulic) Rosendale,	weighs per bbl	280	lbs.
" " Louisville,	" " "	248	"
" " German Portland,	" " "	384	"
" " American,	" " "	288	"
Gypsum, ground	" " "	280	"
Lime, loose	" " "	280	"
Lime, well shaken	" " "	320	"
Sand, at 98 lbs. per square foot	" " "	490	"

Sustaining Power of Soils

Rock, two hundred tons per square foot.

Gravel, eight tons per square foot.

Sand, four tons per square foot.

Clay, four tons per square foot.

Soft clay, one ton per square foot.

Stone, Concrete, Clay Pottery, Etc.

In a standard perch of stone there are 24¾ cubic feet, but 2¾ cubic feet are generally allowed the quarrymen for the mortar and filling. In some communities a short perch of 16½ cubic feet is used.

Material Required
For One Cubic Yard Rammed Concrete

Mixtures			Stone 1 inch and Under Dust Screened Out			Stone 2½ inches and Under Dust Screened Out			Gravel ¾ inch and Under Screened or Washed		
Cement	Sand	Stone	Cement Bbls.	Sand Cu. Yds.	Stone Cu. Yds.	Cement Bbls.	Sand Cu. Yds.	Stone Cu. Yds.	Cement Bbls.	Sand Cu. Yds.	Gravel Cu. Yds.
1	1.0	2.0	2.57	0.39	0.78	2.63	0.40	0.80	2.30	0.35	0.74
1	1.0	2.5	2.29	0.35	0.70	2.34	0.36	0.89	2.10	0.32	0.80
1	1.0	3.0	2.06	0.31	0.94	2.10	0.32	0.96	1.89	0.29	0.86
1	1.0	3.5	1.84	0.28	0.98	1.88	0.29	1.00	1.71	0.26	0.91
1	1.5	2.5	2.05	0.47	0.78	2.09	0.48	0.80	1.83	0.42	0.73
1	1.5	3.0	1.85	0.42	0.84	1.90	0.43	0.87	1.71	0.39	0.78
1	1.5	3.5	1.72	0.39	0.91	1.74	0.40	0.93	1.57	0.36	0.83
1	1.5	4.0	1.57	0.36	0.96	1.61	0.37	0.98	1.46	0.33	0.88
1	1.5	4.5	1.43	0.33	0.98	1.46	0.33	1.00	1.34	0.31	0.91
1	2.0	3.0	1.70	0.52	0.77	1.73	0.53	0.79	1.54	0.47	0.73
1	2.0	3.5	1.57	0.48	0.83	1.61	0.49	0.85	1.44	0.44	0.77
1	2.0	4.0	1.46	0.44	0.89	1.48	0.45	0.90	1.34	0.41	0.81
1	2.0	4.5	1.36	0.42	0.93	1.38	0.42	0.95	1.26	0.38	0.86
1	2.0	5.0	1.27	0.39	0.97	1.29	0.39	0.98	1.17	0.36	0.89
1	2.5	3.5	1.45	0.55	0.77	1.48	0.56	0.79	1.32	0.50	0.70
1	2.5	4.0	1.35	0.52	0.82	1.38	0.53	0.84	1.24	0.47	0.75
1	2.5	4.5	1.27	0.48	0.87	1.29	0.49	0.88	1.16	0.44	0.80
1	2.5	5.0	1.19	0.46	0.91	1.21	0.46	0.92	1.10	0.42	0.83
1	2.5	5.5	1.13	0.43	0.94	1.15	0.44	0.96	1.03	0.39	0.86
1	2.5	6.0	1.07	0.41	0.97	1.07	0.41	0.98	0.98	0.37	0.89
1	3.0	4.0	1.26	0.58	0.77	1.28	0.58	0.78	1.15	0.52	0.72
1	3.0	4.5	1.18	0.54	0.81	1.20	0.53	0.82	1.09	0.50	0.75
1	3.0	5.0	1.11	0.51	0.85	1.14	0.52	0.87	1.03	0.47	0.78
1	3.0	5.5	1.06	0.48	0.89	1.07	0.49	0.90	0.97	0.44	0.81
1	3.0	6.0	1.01	0.46	0.92	1.02	0.47	0.93	0.92	0.42	0.84
1	3.0	6.5	0.96	0.44	0.95	0.98	0.44	0.96	0.88	0.40	0.87
1	3.0	7.0	0.91	0.42	0.97	0.92	0.42	0.98	0.84	0.38	0.89
1	3.5	5.0	1.05	0.56	0.80	1.07	0.57	0.82	0.96	0.50	0.76
1	3.5	5.5	1.00	0.53	0.84	1.02	0.54	0.85	0.92	0.48	0.78
1	3.5	6.0	0.95	0.50	0.87	0.97	0.51	0.89	0.88	0.46	0.80
1	3.5	6.5	0.92	0.49	0.91	0.93	0.49	0.92	0.83	0.44	0.82
1	3.5	7.0	0.87	0.47	0.93	0.89	0.47	0.95	0.80	0.43	0.85
1	3.5	7.5	0.84	0.45	0.96	0.86	0.45	0.98	0.76	0.41	0.87
1	3.5	8.0	0.80	0.42	0.97	0.82	0.43	1.01	0.73	0.39	0.89

Seger Cones

THE Seger cones were developed in Germany by Dr. Herman A. Seger in his life work of putting the clay industry in that country on a scientific basis. They are now made in this country by the following table of chemical formulas and mixture. The analyses of his Zettilitz Kaolin and Rackonitz shale clay, which in nature we term in this country as plastic and flint clays, are as follows, and which he uses as his standard:

	Zettilitz Kaolin	Rackonitz Shale Clay
Silica	46.87	52.50
Alumina	38.56	45.22
Lime	trace	0.50
Iron Oxide	0.83	0.81
Magnesia	trace	0.54
Potash, Soda	1.06	trace
Loss ignition	12.73	0.78
	100.05	100.35

Mechanical Analysis: Rackonitz Shale Clay.

99.27% Clay Substance.

0.73% Sand.

The clay therefore consists of pure clay substance.

The melting point of cones is dependent upon the ratio of alumina to silica and the amount of fluxes contained.

Cone Numbers for Clay Working

The cone numbers used in the different branches of the clay-working industry in the United States are approximately as follows:

Common brick	012–01
Hard-burned, common brick	1– 2
Buff front brick	5– 9
Hollow blocks and fireproofing	03– 1
Terra Cotta	02– 7
Conduits	7– 8
White earthenware	8– 9
Fire bricks	5–18
Porcelain	11–13
Red earthenware	010–05
Stoneware	6– 8

Composition and Fusing-Points of Seger Cones

(Henrich Ries)

No. of Cone	Composition			Fusing-point °Fahr.	Fusing-point °Cent.
.022	$0.5Na_2O$ $0.5PbO$	....	$2.0SiO_2$ $1.0B_2O_3$	1,094	590
.021	$0.5Na_2O$ $0.5PbO$	$0.1Al_2O_3$	$2.2SiO_2$ $1.0B_2O_3$	1,148	620
.020	$0.5Na_2O$ $0.5PbO$	$0.2Al_2O_3$	$2.4SiO_2$ $1.0B_2O_3$	1,202	650
.019	$0.5Na_2O$ $0.5PbO$	$0.3Al_2O_3$	$2.6SiO_2$ $1.0B_2O_3$	1,256	680
.018	$0.5Na_2O$ $0.5PbO$	$0.4Al_2O_3$	$2.8SiO_2$ $1.0B_2O_3$	1,310	710
.017	$0.5Na_2O$ $0.5PbO$	$0.5Al_2O_3$	$3.0SiO_2$ $1.0B_2O_3$	1,364	740
.016	$0.5Na_2O$ $0.5PbO$	$0.55Al_2O_3$	$3.1SiO_2$ $1.0B_2O_3$	1,418	770
.015	$0.5Na_2O$ $0.5PbO$	$0.6Al_2O_3$	$3.2SiO_2$ $1.0B_2O_3$	1,472	800
.014	$0.5Na_2O$ $0.5PbO$	$0.65Al_2O_3$	$3.3SiO_2$ $1.0B_2O_3$	1,526	830
.013	$0.5Na_2O$ $0.5PbO$	$0.7Al_2O_3$	$3.4SiO_2$ $1.0B_2O_3$	1,580	860
.012	$0.5Na_2O$ $0.5PbO$	$0.75Al_2O_3$	$3.5SiO_2$ $1.0B_2O_3$	1,634	890
.011	$0.5Na_2O$ $0.5PbO$	$0.8Al_2O_3$	$3.6SiO_2$ $1.0B_2O_3$	1,688	920
.010	$0.3K_2O$ $0.7CaO$	$0.2Fe_2O_3$ $0.3Al_2O_3$	$3.50SiO_2$ $0.50B_2O_3$	1,742	950
.09	$0.3K_2O$ $0.7CaO$	$0.2Fe_2O_3$ $0.3Al_2O_3$	$3.50SiO_2$ $0.45B_2O_3$	1,778	970
.08	$0.3K_2O$ $0.7CaO$	$0.2Fe_2O_3$ $0.3Al_2O_3$	$3.60SiO_2$ $0.40B_2O_3$	1,814	990
.07	$0.3K_2O$ $0.7CaO$	$0.2Fe_2O_3$ $0.3Al_2O_3$	$3.65SiO_2$ $0.35B_2O_3$	1,850	1,010
.06	$0.3K_2O$ $0.7CaO$	$0.2Fe_2O_3$ $0.3Al_2O_3$	$3.70SiO_2$ $0.30B_2O_3$	1,886	1,030
.05	$0.3K_2O$ $0.7CaO$	$0.2Fe_2O_3$ $0.3Al_2O_3$	$3.75SiO_2$ $0.25B_2O_3$	1,922	1,050
.04	$0.3K_2O$ $0.7CaO$	$0.2Fe_2O_3$ $0.3Al_2O_3$	$3.80SiO_2$ $0.20B_2O_3$	1,958	1,070
.03	$0.3K_2O$ $0.7CaO$	$0.2Fe_2O_3$ $0.3Al_2O_3$	$3.85SiO_2$ $0.15B_2O_3$	1,994	1,090
.02	$0.3K_2O$ $0.7CaO$	$0.2Fe_2O_3$ $0.3Al_2O_3$	$3.90SiO_2$ $0.10B_2O_3$	2,030	1,110
.01	$0.3K_2O$ $0.7CaO$	$0.2Fe_2O_3$ $0.3Al_2O_3$	$3.95SiO_2$ $0.05B_2O_3$	2,066	1,130
1	$0.3K_2O$ $0.7CaO$	$0.2Fe_2O_3$ $0.3Al_2O_3$	$4SiO_2$	2,102	1,150
2	$0.3K_2O$ $0.7CaO$	$0.1Fe_2O_3$ $0.4Al_2O_3$	$4SiO_2$	2,138	1,170
3	$0.3K_2O$ $0.7CaO$	$0.05Fe_2O_3$ $0.45Al_2O_3$	$4SiO_2$	2,174	1,190

Composition and Fusing-Points of Seger Cones

(Continued)

No. of Cone	Composition			Fusing-point °Fahr.	Fusing-point °Cent.
4	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$0.5\ Al_2O_3$	$4SiO_2$	2,210	1,210
5	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$0.5\ Al_2O_3$	$5SiO_2$	2,246	1,230
6	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$0.6\ Al_2O_3$	$6SiO_2$	2,282	1,250
7	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$0.7\ Al_2O_3$	$7SiO_2$	2,318	1,270
8	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$0.8\ Al_2O_3$	$8SiO_2$	2,354	1,290
9	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$0.9\ Al_2O_3$	$9SiO_2$	2,390	1,310
10	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$1.0\ Al_2O_3$	$10SiO_2$	2,426	1,330
11	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$1.2\ Al_2O_3$	$12SiO_2$	2,462	1,350
12	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$1.4\ Al_2O_3$	$14SiO_2$	2,498	1,370
13	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$1.6\ Al_2O_3$	$16SiO_2$	2,534	1,390
14	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$1.8\ Al_2O_3$	$18SiO_2$	2,570	1,410
15	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$2.1\ Al_2O_3$	$21SiO_2$	2,606	1,430
16	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$2.4\ Al_2O_3$	$24SiO_2$	2,642	1,450
17	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$2.7\ Al_2O_3$	$27SiO_2$	2,678	1,470
18	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$3.1\ Al_2O_3$	$31SiO_2$	2,714	1,490
19	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$3.5\ Al_2O_3$	$35SiO_2$	2,750	1,510
20	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$3.9\ Al_2O_3$	$39SiO_2$	2,786	1,530
21	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$4.4\ Al_2O_3$	$44SiO_2$	2,822	1,550
22	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$4.9\ Al_2O_3$	$49SiO_2$	2,858	1,570
23	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$5.4\ Al_2O_3$	$54SiO_2$	2,894	1,590
24	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$6.0\ Al_2O_3$	$60SiO_2$	2,930	1,610
25	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$6.6\ Al_2O_3$	$66SiO_2$	2,966	1,630
26	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$7.2\ Al_2O_3$	$72SiO_2$	3,002	1,650
27	$\left\{\begin{array}{l}0.3K_2O\\0.7CaO\end{array}\right\}$	$20\ Al_2O_3$	$200SiO_2$	3,038	1,670

Composition and Fusing-Points of Seger Cones

(Continued)

No. of Cone	Composition	Fusing-point °Fahr.	Fusing-point °Cent.
28	$\left\{ \begin{matrix} 0.3K_2O \\ 0.7CaO \end{matrix} \right\} Al_2O_3 \quad 10SiO_2$	3,074	1,690
29	$Al_2O_3 \quad 10SiO_2$	3,110	1,710
30	$Al_2O_3 \quad 8SiO_2$	3,146	1,730
31	$Al_2O_3 \quad 6SiO_2$	3,182	1,750
32	$Al_2O_3 \quad 5SiO_2$	3,218	1,770
33	$Al_2O_3 \quad 3SiO_2$	3,254	1,790
34	$Al_2O_3 \quad 2.5SiO_2$	3,290	1,810
35	$Al_2O_3 \quad 2SiO_2$	3,326	1,830
36	$Al_2O_3 \quad 1.5SiO_2$	3,362	1,850
37		3,398	1,880
38		3,434	1,910
39		3,470	1,940

Elements Corresponding to the Symbols Appearing in the Foregoing Table

Name	Symbol	Name	Symbol
Alumina	(Al_2O_3)	Lime	(CaO)
Borax	(B_2O_3)	Potash	(K_2O)
Ferric Oxide	(Fe_2O_3)	Silica	(SiO_2)
Lead	(PbO)	Soda	(Na_2O_3)

Table of The Elements and their Atomic Weights

Name	Symbol	Atomic Weight O=16	Name	Symbol	Atomic Weight O=16
Aluminium	Al	27.1	Neodymium	Nd	143.6
Antimony	Sb	120.2	Neon	Ne	20.
Argon	A	39.9	Nickel	Ni	58.7
Arsenic	As	75.0	Nitrogen	N	14.04
Barium	Ba	137.4	Osmium	Os	191.
Bismuth	Bi	208.5	Oxygen	O	16.00
Boron	B	11.0	Palladium	Pd	106.5
Bromine	Br	79.96	Phosphorus	P	31.0
Cadmium	Cd	112.4	Platinum	Pt	194.8
Cæsium	Cs	132.9	Potassium	K	39.15
Calcium	Ca	40.1	Praseodymium	Pr	140.5
Carbon	C	12.00	Radium	Ra	225.
Cerium	Ce	140.25	Rhodium	Rh	103.0
Chlorine	Cl	35.45	Rubidium	Rb	85.5
Chromium	Cr	52.1	Ruthenium	Ru	101.7
Cobalt	Co	59.0	Samarium	Sm	150.3
Columbium	Cb	94.	Scandium	Sc	44.1
Copper	Cu	63.6	Selenium	Se	79.2
Erbium	Er	166.	Silicon	Si	28.4
Fluorine	F	19.	Silver	Ag	107.93
Gadolinium	Gd	156.	Sodium	Na	23.05
Gallium	Ga	70.	Strontium	Sr	87.6
Germanium	Ge	72.5	Sulphur	S	32.06
Glucinum	Gl	9.1	Tantalum	Ta	183.
Gold	Au	197.2	Tellurium	Te	127.6
Helium	He	4.	Terbium	Tr	160.
Hydrogen	H	1.008	Thallium	Tl	204.1
Indium	In	115.	Thorium	Th	232.5
Iodine	I	126.97	Thulium	Tm	171.
Iridium	Ir	193.0	Tin	Sn	119.0
Iron	Fe	55.9	Titanium	Ti	48.1
Krypton	Kr	81.8	Tungsten	W	184.
Lanthanum	La	138.9	Uranium	U	238.5
Lead	Pb	206.9	Vanadium	V	51.2
Lithium	Li	7.03	Xenon	X	128.
Magnesium	Mg	24.36	Ytterbium	Yb	173.0
Manganese	Mn	55.0	Yttrium	Y	89.0
Mercury	Hg	200.00	Zinc	Zn	65.4
Molybdenum	Mo	96.00	Zirconium	Zr	90 6

Special Glasshouse Data

Temperature Constants for Glass Working

	Fahr.	Cent.
Glass Furnace, between pots	2507	1375
In the pots, refining	2390	1310
In the pots, working	1913	1045
	Fahr.	**Cent.**
Annealing Glassware	800° to 1000°	444° to 555°

Rule for calculating amount of invoice for Soda Ash 58%, billed at certain price based on 48% Soda Ash.

RULE:

Divide value @ 48% base of invoice by 6.
Divide quotient by 4.
Add dividend and two quotients.
Result = Value @ 58%.

EXAMPLE:

James Ashley & Co.
10 bbls. 58% Soda Ash.
4830 lbs. @ 85 cents 48% base = \$49.61.
4830 × 85 cents = \$41.0550.
\$41.0550 ÷ 6 = 6.8425.
6.8425 ÷ 4 = 1.71062.
41.0550 + \$6.8425 + \$1.71062 = \$49.608 for 58%.

Washing Iron from Chest Cullet

The following process of washing iron from chest cullet should be conducted in a wash house located outside of the factory building and as near to the boiler or boilers as possible.

The former is advisable on account of the obnoxious fumes given off during the washing process and the latter, for the sake of economy in the use of steam.

Select a common oil barrel, replace the iron hoops with copper hoops; bore a hole near the bottom to drain the acid solution after washing; and provide a wooden plug to close the hole while washing.

As dry steam must be used to boil the solution, insert a piece of ¾-inch lead pipe about 4 feet long in the barrel through the top, which is left open. The lead pipe should be placed within three or four inches of the bottom and should be connected to steam pipe with a piece of rubber hose so as to be easily detached. A valve should be placed at a convenient point in the steam line to shut off steam. The barrel should be mounted on two trunnions or spindles so as to be easily turned over to discharge the glass contents.

Operation

First plug hole in bottom, insert lead steam pipe; then fill with cullet; pour in muriatic acid diluted with water 25% to 50% to almost cover the glass; then turn on steam. In five minutes after the acid boils the steam can be turned off, acid drained off and the glass taken out, leaving the barrel ready for the next washing.

The washed glass should be well rinsed with water from a hose.

The glass should be dumped on a grating or perforated floor to enable the water to drain off easily. The hole in the barrel for drawing off the acid should be on the opposite side from the place where the glass is dumped. The acid must be drained into a glass receptacle or a wooden one with copper hoops. The receptacle should be provided with a hoist for purposes of raising and pouring the acid back into the barrel. The acid can be used repeatedly, but it must be understood that the acid is weakened each time by condensation of steam, diluting it with water so that it is necessary to occasionally renew the old solution by the addition of a little new stock.

If the above is rigged up in the right manner two men can, in a day's time, wash a week's accumulated glass from one furnace.

Precautions

Use only lead, wood, glass or rubber in the acid. Do not use anything with iron in it. The men can wear rubber gloves and boots. While copper may be used, it will not entirely resist the action of the acid.

Painting

For outside woodwork, paint made from white lead, ground in linseed oil, is most used. If the oil is raw, or unboiled, *dryer* is added; if boiled, no dryer is necessary. Not less than four coats should be applied, five are better.

Paint, ready mixed, put up in cans or kegs, may be procured from manufacturers or dealers. These paints have to be thinned by adding one pint of oil to about 2½ pounds of paint. When thinned, one pound will cover about two square yards of first coat, three yards of second and four yards of each subsequent coat; or 1⅜ pounds to the square yard will be required for four coats and 1⅝ pounds for five coats.

For inside work, whether white lead or oxide of zinc is used, and for good work four coats are necessary.

For iron exposed to the weather, metallic paints, such as yellow and red iron ochres or brown hematite ore, finely pulverized and mixed with oil or dryer, are best.

For black iron, galvanized iron and tin surfaces, one gallon of paint will cover 250 to 350 square feet as a first coat, depending on the character of the surface, and from 360 to 450 as a second coat.

For iron subject to the action of water, red lead is best.

Plastered walls should stand a year before painting.

Painting is measured by the square yard, girding every part of the work that is covered by paint and allowing an addition to the actual surface for the difficulty of covering deep quirk of mouldings and for "cutting in" as in sash and shelving, or where there is a change in color, on the same work.

Washes

For outside woodwork. In a tight barrel, slake a half bushel of fresh lime by pouring over it boiling water sufficient to cover it four or five inches deep, stir until slaked; add two pounds of sulphate of zinc dissolved in water, add water enough to bring all to the consistency of thick whitewash.

For inside woodwork. Add two quarts of thin size to a pail full of wash just before using. A common practice of mixing salt with whitewash should not be permitted.

For brick or stonework. Slake one-half bushel of lime, as before, in a barrel; then fill the barrel two-thirds full of water and add a bushel of hydraulic cement; add three pounds of sulphate of zinc dissolved in water. These washes may be colored by adding powdered ochre, umber, etc.

Mensuration

Weights and Measures

THE Standard Unit of the U. S. and British Linear Measure is the yard. It was intended to be exactly the same for both countries, but in reality the U. S. yard exceeds the British Standard by .00087 inch. The actual standard of length of the U. S. is a brass scale 82 inches long prepared for the Coast Survey and deposited in the office of Weights and Measures at the U. S. Treasury Department, Washington, D. C. The yard is between the 27th and 63rd inches of this scale. The temperature at which this scale is designed to be standard, and at which it is used in the U. S. Coast Survey, is 62° Fahrenheit.

Dry Measure

PINTS = 33.6 cubic inches.

2 =	1 quart = 67.2 cubic inches.							
8 =	4 "	= 1 gallon = 268.8 cubic inches.						
16 =	8 "	= 2 "	= 1 peck = 537.6 cubic inches.					
64 =	32 "	= 8 "	= 4 "	= 1 bushel = 2150.4 cubic inches.				

NOTE: The standard U. S. bushel is the Winchester bushel, which is in cylinder form, 18½ inches diameter and eight inches deep and contains 2150 42-100 cubic inches.

Liquid or Wine Measure

GILLS = 7.2187 cubic inches.

4 =	1 pint =	28.875 cubic inches.				
8 =	2 " =	1 quart =	57.75 cubic inches.			
32 =	8 " =	4 " =	1 gallon = 231 cubic inches.			
2016 =	404 " =	252 " =	63 "	= 1 hogshead.		
4032 =	1008 " =	504 " =	126 "	= 2 "	= 1 pipe.	
8064 =	2016 " =	1008 " =	252 "	= 4 "	= 2 "	= 1 tun.

NOTE: The standard Unit of Liquid Measure adopted by the U. S. Government is the Winchester Wine Gallon, which contains 231 cubic inches and holds 8.339 pounds avoir. of distilled water, at its maximum density, weighed in air, the barometer being at 30 inches.

The Imperial gallon adopted by Great Britain contains 277.274 cubic inches and 1.20032 U. S. gallons.

Long Measure

INCHES

12 =	1 foot.					
36 =	3 feet =	1 yard.				
72 =	6 " =	2 " =	1 fathom.			
198 =	16.5 " =	5.5 " =	2.75 " =	1 perch or rod.		
7920 =	660 " =	220 " =	110 " =	40 "	= 1 furlong.	
63360 =	5280 " =	1760 " =	880 " =	320 "	= 8 "	= 1 mile.

Gunter's Chain

INCHES

7.92 =	1 link.		
792 =	100 " =	1 chain.	
63360 =	8000 " =	80 "	= 1 mile.

Nautical Measure

NAUTICAL MILE

1 =	6086 feet.	
3 =	1 league.	
60 =	20 "	= 1 degree = 69.16 English miles.

Square Measure

SQUARE INCHES

144 =	1 sq. foot.				
1296 =	9 feet =	1 sq. yard.			
39204 =	272.25 " =	30.25 " =	1 sq. perch.		
1568160 =	10890 " =	1210 " =	40 "	= 1 sq. rod.	
6272640 =	43560 " =	4840 " =	160 "	= 4 sq. rod = 1 acre.	

An acre is 69.5701 yards square, or 208.710321 feet square.

A township is	6 miles square	=	36 sections.
Section	" 1 mile "	=	640 acres.
¼ "	" ½ " "	=	160 "
$\frac{1}{16}$ "	" ¼ " "	=	40 "

Solid Measure

CUBIC INCHES

1728 = 1 cubic foot.
46656 = 27 cubic feet = 1 cubic yard.
2,150.42 = 1 standard bushel.
268.8 = 1 standard gallon.
1 cubic foot = about $\frac{4}{5}$ of a bushel.
128 cubic feet = 1 cord (wood).

Register Ton: For register tonnage or for measurement of the entire internal capacity of a vessel.
100 cubic feet = 1 Register Ton.

Shipping Ton: For the measurement of cargo.
40 cubic feet = 1 U. S. Shipping Ton.

Troy Weight

GRAINS

24 = 1 dwt.
480 = 20 dwt. = 1 oz.
5760 = 240 dwt. = 12 oz. = 1 lb. = 22.816 cubic inches of distilled water at 62° Fahr.

The U. S. standard of weight is the Troy pound and was copied in 1827 from the Imperial Troy pound of England for the use of the U. S. Mint, and there deposited. It is standard in air, at 62° Fahr. the barometer at 30 inches.

Avoirdupois Weight

DRACHMS

16 =	1 oz. =	437.5 grains Troy			
256 =	16 oz. =	7000 grains =	1 lb.		
6400 =	400 oz. =	175000 grains =	25 lb. =	1 quarter.	
25600 =	1600 oz. =	700000 grains =	100 lb. =	4 "	= 1 cwt.
512000 =	32000 oz. =	14000000 grains =	2000 lb. =	80 "	= 20 cwt. = 1 ton.

Apothecaries' Weight

GRAINS

20 =	1 scruple		
60 =	3 "	= 1 drachm	
480 =	24 "	= 8 "	= 1 oz.
5760 =	288 "	= 96 "	= 12 oz. = 1 lb.

Apothecaries' Measure

60 min. = 1 fluid drachm.
8 fluid drachms = 1 fluid ounce.
16 fluid ounces = 1 pint.
8 pints = 1 gallon.

45 drops, or a common teaspoonful, make about one fluid drachm; two tablespoonfuls, about one fluid ounce; a wineglassful about 1½ fluid ounces and a teacupful about four fluid ounces.

Equivalents of Various Measures and Weights

	U. S. Gallon	Cubic Inch	Cubic Foot	Pound	Cwt.	Ton
U. S. Gallon	1.	231.	.133	8.33	.07455	.00372
Cubic Inch	.004329	1.	.000058	.03607	. . . .	. . . .
Cubic Foot	7.48	1728.	1.	62.35	.557	.028
Pound	.083	27.72	.016	1.	.0089	.00044
Cwt.	13.44	. . . .	1.8	112.00	1.	20.
Ton	268.8	. . . .	35.9	2240.	20.	1.

Equivalents of Surfaces and Volumes

Lineal feet	×	.00019	=	Miles
" yards	×	.00057	=	"
Square inches	×	.007	=	Square feet
" feet	×	.111	=	" yards
" yards	×	.0002067	=	Acres
Acres	×	4840	=	Square yards
Cubic inches	×	.00058	=	Cubic feet
" feet	×	.03704	=	" yards
Circular inches	×	.00546	=	Square feet
Cyl. inches	×	.0004546	=	Cubic feet
" feet	×	.02909	=	" yards
Links	×	.22	=	Yards
"	×	.66	=	Feet
Feet	×	1.5	=	Links
Width, in chains	×	8.	=	Acres per mile
183346 circular inches			=	1 square foot
2200 cylindrical inches			=	1 cubic foot
Cubic feet	×	7.48	=	U. S. gallons
" inches	×	.004329	=	U. S. gallons
U. S. gallons	×	.13367	=	Cubic feet
U. S. gallons	×	231.	=	" inches
Cubic feet	×	.8036	=	U. S. bushel
" inches	×	.000466	=	" "
Cyl. feet of water	×	6.	=	U. S. gallons
Lbs. Avoirdupois	×	.009	=	cwt. (112)
" "	×	.00045	=	Tons (2240)
Cubic feet of water	×	62.5	=	Lbs. Avoir.
" inch of water	×	.03617	=	" "
Cyl. feet water	×	49.1	=	" "
Cyl. inch water	×	.02842	=	" "
13.44 U. S. gallons of water			=	1 cwt.
268.8 " " "			=	1 ton
1.8 cubic feet of water			=	1 cwt.
35.88 " " " "			=	1 ton
Column of water 12 inches high, and 1 inch in diameter			=	.341 Lbs.
U. S. bushel	×	.0495	=	Cubic yards
" "	×	1.2446	=	" feet
" "	×	2150.42	=	inches

Area of rectangle = length × breadth.
Area of triangle = base ½ perpendicular height.
Diameter of circle = radius × 2.
Circumference of circle = diameter × 3.1416.
Area of circle = square of diameter × .7854.

$$\text{Area of sector of circle} = \frac{\text{area of circle} \times \text{number of degrees in arc.}}{360}$$

Area of surface of cylinder = circumference × length + area of two ends.
To find diameter of circle having given area: Divide the area by .7854 and extract the sq. root.
To find the volume of a cylinder: Multiply the area of the section in square inches by the length in inches = the volume in cubic inches. Cubic inches divided by 1728 = volume in cu. ft.
Surface of a sphere = square of diameter × 3.1416.
Solidity of a sphere = cube of diameter × .5236.
Side of an inscribed cube = radius of a sphere × 1.1547.
Area of the base of a pyramid or cone, whether round, square or triangular, multiplied by one-third of its height = the solidity.
Diameter × .8862 = side of an equal square.
Diameter × .7071 = side of an inscribed square.
Radius × 6.2832 = circumference.
Circumference = $3.5446 \times \sqrt{\text{Area of circle.}}$
Diameter = $1.1283 \times \sqrt{\text{Area of circle.}}$
Length of arc = No. of degrees × .017453 radius.
Degrees in arc whose length equals radius = 57° 2958′.
Length of an arc of 1° = radius × .017453.
" " " " 1 Min. = radius × .0002909.
" " " " 1 Sec. = radius × .0000048.

π = Proportion of circumference to diameter = 3.1415926.
π^2 = 9.8696044. $1/\pi$ = 0.31831.
$\sqrt{\pi}$ = 1.7724538. $1/360$ = .002778.
Log. = 0.49715. $360/\pi$ = 114.59.

French or Metric System of Measures

THIS system, first adopted by France, has been extensively adopted by other countries, and is much used in the sciences and the arts. It was legalized in 1866 by Congress to be used in the United States, and is already employed by the Coast Survey, and to some extent by the Mint and the General Post Office. The names of derived metric denominations are formed by prefixing to the name of the primary unit of a measure.

Mille	(mill'e)	a thousandth	Hecto	(hek'to)	one hundred
Centi	(sent'e)	a hundredth	Kilo	(kilo)	a thousand
Deci	(des'e)	a tenth	Myria	(mir'ea)	ten thousand

Deka (dek'a) ten

Lineal Measure

	Metres	U.S. Inches	Feet	Yards	Miles
Millemetre*	.001	.03937	.00328	....	....
Centimetre†	.01	.3937	.03280	....	....
Decimetre	.1	3.937	.32807	.10936	....
Metre	1.	39.3685	3.2807	1.0936	....
Decametre	10.	....	32.807	10.936	....
Hectometre	100.	....	328.07	109.36	.0621347
Kilometre	1000.	....	3280.7	1093.6	.6213466
Myriametre	10000.	....	32807.	10936.	6.213466

*Nearly the 1/25 part of an inch. †Full 3/8 inch.

Square Measure

	Square Metres	U.S. Square Inches	Square Feet	Square Yards	Acres
Square Centimetre	.01	.155	....	....	....
Square Decimetre	.1	15.5	.10763	.01196	....
Centiare	1.	1549.88	10.763	1.196	.00025
Are	10.	154988.	1076.3	119.6	.0247
Hectare	100.	....	107630.	11959.	2.47
Square Kilometre	.38607	....	....	....	247.
Square Myriametre	38 607	....	....	....	24708.

Cubic or Solid Measure

	Cubic Metres	U. S. Cubic Inches	U. S. Cubic Feet	U. S. Cubic Yards
Cubic Centimetre	.0001	.0610165	......	......
Cubic Decimetre	.001	61.0165	......	......
Centistre	.01	610.165	.353105	......
Decistre	.1	6101.65	3.53105	.13078
Stere	1.	......	35.3105	1.3078
Decastere	10.	......	353.105	13.078
Hectostere	100.	......	3531.05	130.78

Metric or French Weights

	Grammes	Troy Grains	Avoirdupois Ounces	Avoirdupois Pounds
Millegramme	.001	.01543	......	.....
Centigramme	.01	.15433	......	.....
Decigramme	.1	1.5433	......	.....
Gramme	1.	15.43316	.03528	.0022047
Decagramme	10.	......	.3528	.022047
Hectogramme	100.	......	3.52758	.2204737
Kilogramme	1000.	......	35.2758	2.204737
Myriogramme	10000.	......	......	22.04737
Quintal	100000.	......	......	220.4737
Tonneau	1000000.	......	......	2204.737

Metric or French Capacity Measure

French	U. S.	Dry Measure	U. S. Liquid or Wine Measure
1 Millilitre =	.061 cu. in. =	.0018 pts.	.27 fluid dm.
1 Centilitre =	.6102 " =	.018 "	.338 " oz.
1 Decilitre =	6.1023 " =	.18 "	.845 " gills.
1 Litre =	61.02 " =	.908 qts. = 1.8 pts.	1.0567 quarts
1 Decalitre =	610.16 " =	9.08 " = 18.16 "	2.641 gallons
1 Hectolitre =	3.531 cu. ft. =	11.321 pks. (2.837 bu.)	26.41 "
1 Kilolitre =	35.31 " =	28.37 "	264.14 "
1 Myralitre =	353.1 " =	283.7 "	2641.4 "

Table of Decimal Equivalents of Millimeters and Fractions of Millimeters

$\frac{1}{100}$ Mm = .0003937 Inches

Mm.	Inches	Mm.	Inches	Mm.	Inches
$\frac{1}{50}$	=.00079	$\frac{26}{50}$	=.02047	2	= .07874
$\frac{2}{50}$	=.00157	$\frac{27}{50}$	=.02126	3	= .11811
$\frac{3}{50}$	=.00236	$\frac{28}{50}$	=.02205	4	= .15748
$\frac{4}{50}$	=.00315	$\frac{29}{50}$	=.02283	5	= .19685
$\frac{5}{50}$	=.00394	$\frac{30}{50}$	=.02362	6	= .23622
$\frac{6}{50}$	=.00472	$\frac{31}{50}$	=.02441	7	= .27559
$\frac{7}{50}$	=.00551	$\frac{32}{50}$	=.02520	8	= .31496
$\frac{8}{50}$	=.00630	$\frac{33}{50}$	=.02598	9	= .35433
$\frac{9}{50}$	=.00709	$\frac{34}{50}$	=.02677	10	= .39370
$\frac{10}{50}$	=.00787	$\frac{35}{50}$	=.02756	11	= .43307
$\frac{11}{50}$	=.00866	$\frac{36}{50}$	=.02835	12	= .47244
$\frac{12}{50}$	=.00945	$\frac{37}{50}$	=.02913	13	= .51181
$\frac{13}{50}$	=.01024	$\frac{38}{50}$	=.02992	14	= .55118
$\frac{14}{50}$	=.01102	$\frac{39}{50}$	=.03071	15	= .59055
$\frac{15}{50}$	=.01181	$\frac{40}{50}$	=.03150	16	= .62992
$\frac{16}{50}$	=.01260	$\frac{41}{50}$	=.03228	17	= .66929
$\frac{17}{50}$	=.01339	$\frac{42}{50}$	=.03307	18	= .70866
$\frac{18}{50}$	=.01417	$\frac{43}{50}$	=.03386	19	= .74803
$\frac{19}{50}$	=.01496	$\frac{44}{50}$	=.03465	20	= .78740
$\frac{20}{50}$	=.01575	$\frac{45}{50}$	=.03543	21	= .82677
$\frac{21}{50}$	=.01654	$\frac{46}{50}$	=.03622	22	= .86614
$\frac{22}{50}$	=.01732	$\frac{47}{50}$	=.03701	23	= .90551
$\frac{23}{50}$	=.01811	$\frac{48}{50}$	=.03780	24	= .94488
$\frac{24}{50}$	=.01890	$\frac{49}{50}$	=.03858	25	= .98425
$\frac{25}{50}$	=.01969	1	=.03937	26	=1.02362

10 Mm. = 1 Centimeter = 0.3937 Inches.
10 Cm. = 1 Decimeter = 3.937 Inches.
10 Dm. = 1 Meter = 39.37 Inches.
25.4 Mm. = 1 English Inch.

A Convenient Metric Conversion Table

Millimeters × .03937 = inches.
Millimeters 25.4 = inches.
Centimeters × .3937 = inches.
Centimeters 2.54 = inches.
Meter = 39.37 inches. (Act of Congress).
Meters × 3.281 = feet.
Meters × 1.094 = yards.
Kilometers × .621 = miles.
Kilometers × 3280.7 = feet.
Square Millimeters × .0155 = square inches.
Square Millimeters ÷ 645.1 = square inches.
Square Centimeters × .155 = square inches.
Square Centimeters ÷ 6.451 = square inches.
Square Meters × 10.764 = square feet.
Square Kilometers × 247.1 = acres.
Hectares × 2.471 = acres.
Cubic Centimeters ÷ 16.383 = cubic inches.
Cubic Meters × 35.315 = cubic feet.
Cubic Meters × 1.308 = cubic yards.
Cubic Meters × 264.2 = gallons. (231 cubic inches).
Liters × 61.022 = cubic inches. (Act of Congress).
Liters × .2642 = gallons. (231 cubic inches).
Liters ÷ 3.78 = gallons. (231 cubic inches).
Liters ÷ 28316 = cubic feet.
Grammes × 15.432 = grains. (Act of Congress).
Grammes (water) ÷ 29.57 = fluid ounces.
Grammes ÷ 28.35 = ounces avoirdupois.
Grammes per cubic cent. ÷ 27.7 = pounds per cubic inch.
Joule × .7373 = foot pounds.
Kilograms × 2.2046 = pounds.
Kilograms × 35.3 = ounces avoirdupois.
Kilograms ÷ 1102.3 = tons. (2000 pounds).
Kilograms per square cent. × 14.223 pounds per square inch.
Kilowatts × 1.35 = horse power.
Watts ÷ 746 = horse power.
Calorie × 3.968 = B. T. U.
Cheval vapeur × .9863 = horse power.
(Centigrade × 1.8) + 32 = degrees Fahrenheit.
Francs × .193 = dollars.

Algebraic and Arithmetical Signs Used in Calculations

$\times$ signifies the ratio of the circumference of circle to its diameter = 3.1416.

= equal to, as 12 inches = 1 foot or 2 added to 5 = 7.

+ plus, signifies addition, as $4 + 6 = 10$.

— minus, signifies subtracting, as $15 - 5 = 10$.

$\times$ multiplied by, signifies multiplications, as $8 \times 9 = 72$.

$\div$ divided by, signifies division, as $16 \div 4 = 4$.

Division is also indicated by placing the dividend above a short line and the divisor below it; thus:

$$\frac{\text{Dividend } 10}{\text{Divisor } \quad 5} = 2.$$

$\sqrt{\ }$ Signifies that the square root of the number or symbol to which it is prefixed is required, as $\sqrt{16} = 4$.

$\sqrt[3]{\ }$ That the cube root is required; $\sqrt[3]{27} = 3$.

$\sqrt[4]{\ }$ That the fourth root is required; $\sqrt[4]{81} = 3$.

5^2 Signifies that 5 is to be squared; $5^2 = 25$.

5^3 Signifies that 5 is to be cubed; $5^3 = 125$.

— Vinculum or bar, signifies that the numbers of symbols over which it is placed are to be taken together, as $\overline{3 + 6} \times 5 = 45$.

. Decimal point, as .1 = 1/10; 1.4 = 1 4/10.

( ) Parentheses, signifies that all the numbers or symbols between are to be taken as if they were only one.

°, ′, ″ Signifies degrees, minutes and seconds.

: Signifies proportion, as 2: 4: 8: 16:, that is, 2 is to 4 as 8 is to 16.

Iron, Steel and Other Metals

STEEL is a compound of iron and carbon, varying in proportion of 0.5 per cent to 5 per cent of carbon. Specific gravity 7.8; tensile strength, 120,000 lbs. per square inch. Ordinary steel is carbon steel, but steely compounds of iron have been produced which have the same general properties as ordinary steel, the carbon of which is replaced by other chemical elements.

To test steel and iron:

Nitric acid will produce a black spot on steel; the darker the spot, the harder the steel. Iron, on the contrary, remains bright if touched with nitric acid. Good steel in its soft state has a curved fracture and a uniform gray lustre; in its hard state a dull, silvery uniform white. Cracks, threads or sparkling particles denote bad quality.

Good steel will not bear a white heat without falling into pieces, and will crumble under the hammer at a bright red heat, while at a middling heat it may be drawn out under the hammer to a fine point.

Light iron indicates impurity.

Heaviest steel contains least carbon.

Notes on the Working of Steel

Good soft heat is safe to use if steel be immediately and thoroughly worked. It is a fact that good steel will endure more pounding than any iron.

If steel be left long in the fire it will lose its steely nature and grain, and partake of the nature of cast iron.

Steel should never be kept hot any longer than is necessary for the work to be done.

Steel is entirely mercurial under the action of heat, and a careful study will show that there must of necessity be an injurious internal strain created whenever two or more parts of the same piece are subjected to different temperatures.

It follows that when steel has been subjected to heat not absolutely uniform over the whole mass, careful annealing should be resorted to.

As the change of volume due to a degree of heat increases directly and rapidly with the quantity of carbon present, therefore, high steel is more liable to dangerous internal strains than low steel, and great care should be exercised in the use of high steel.

Hot steel should always be put in a perfectly dry place of even temperature while cooling. A wet place in the floor might be sufficient to cause serious injury.

Be careful not to overdo the annealing process; if carried too far it does great harm, and it is one of the commonest modes of destruction which the steel maker meets in his daily troubles. It is hard to induce the average worker in steel to believe that very little annealing is necessary, and that a very little is really more efficacious than a great deal.

The breaking strain of iron and steel does not (as hitherto assumed) indicate the quality. A high-breaking strain may be due to hard, unyielding character, or a low one may be due to extreme softness. The contraction of area at the fracture forms an essential element in estimating the quality.

Iron when fractured suddenly produces a crystalline fracture; but if gradually, a fibrous fracture. This accounts for the anomaly in the supposed change of iron from a fibrous to a crystalline character.

Sudden shoulders, which prevent a regular elongation of fibre, causes a sudden snap.

Strength of steel is reduced by being hardened in water; but both its hardness and toughness are increased by being hardened in oil. Iron heated and suddenly cooled in water is hardened and the breaking strain (if gradually applied) is increased, but it is more likely to snap suddenly. It is softened and its breaking strain reduced if heated and allowed to cool gradually. Iron, if brought to a white heat is injured if it be not at the same time hammered or rolled. Case-hardening bolts weaken them.

Foreign Substances in Iron and Steel

Silicon: Is generally excluded as slag, its presence makes iron hard and brittle; but up to .08% it will do no harm, provided .3% of manganese is present with it.

Sulphur: Makes iron and steel "red-short."

Phosphorous: .5% to .8% is sufficient to produce cold-shortness in iron; in steel, phosphorous to an extent of .2% does not affect the working or hammering of steel.

Manganese: .5% is sufficient to make iron "cold-short;" it is valuable in iron to be converted into steel.

Arsenic: Produces red-shortness in iron, but is valuable in chilling; it increases the hardness in steel at the expense of toughness.

Copper: Renders steel red-short.

Tungsten: Renders steel hard and tenacious.

Vanadium: Improves the ductility of iron for wire-drawing.

Carbon: .25% gives malleable iron; .5% gives steel; 1.75% gives the limit of welding steel; 2.0% gives the lowest limit of cast iron.

Computing Weight of Iron and Steel

Cast iron is 17½ times heavier than ordinary kiln-dried wood, used in common patterns.

To compute the weight of sheet steel, divide the thickness, expressed in thousandths, by 25; the result is the weight, in pounds, per square foot.

For weight of sheet brass, add 11 per cent.

For weight of sheet copper, add 10 per cent.

To find the weight of round iron, per foot in length, square the diameter, expressed in quarter inches and divide by 6. Thus, a 1¼″ rod weighs $5^2 = 25$; $25 \div 6 = 4\frac{1}{6}$ lbs. per foot.

To find the weight of square or flat iron, per yard in length, multiply the area of width and thickness by 10. Thus, a bar 2 × ⅜ has an area of ¾ square inch, and weighs ¾ × 10 = 7½ lbs. per yard.

To find the tensile strength of round iron, square the diameter expressed in quarters; the result will be its (tearing) strength (approximately) in tons. Thus, a rod ¼″ in diameter will sustain one ton; $\frac{2}{4}$″ or ½″, four tons; ¾″, nine tons; $\frac{4}{4}$ or 1″, sixteen tons, etc. If square, and same thickness, it will bear about ¼ more; hence, a bar 1″ square will sustain about twenty tons.

The average weight of wrought iron is 480 lbs. per cubic foot. A bar 1″ square and 3′ long weighs, therefore, exactly 10 lbs. Hence,

To find the sectional area, given the weight per foot—multiply by $\frac{3}{10}$.

To find the weight per foot, given the sectional area—multiply by $\frac{10}{3}$.

The weight of steel is two per cent greater than that of wrought iron.

Weight of Castings from Patterns

A Pattern Weighing One Pound Made of	Will Weigh When Cast In				
	Cast Iron Lbs.	Zinc Lbs.	Copper Lbs.	Yellow Brass Lbs.	Gun Metal Lbs.
Mahogany—Nassau	10.7	10.4	12.8	12.2	12.5
" —Honduras	12.9	12.7	15.3	14.6	15.
" —Spanish	8.5	8.2	10.1	9.7	9.9
Pine—Red	12.5	12.1	14.9	14.2	14.6
" —White	16.7	16.1	19.8	19.	19.5
" —Yellow	14.1	13.6	16.7	16.	16.5
Oak	9.	8.6	10.4	10.1	10.9

Method of Computing Weight of Iron Castings

Multiply the volume of the finished casting in cubic inches by .261.

EXAMPLE: Find the weight of a cast iron plate of dimensions 12″ × 24″ × 1″.

12″ × 1″ = 12 cubic inches.=Sectional area.
12″ × 24″ = 288 cubic inches.=Volume of plate.
288 × .261 = 75.168 lbs. =Weight of plate.

To Convert the Weight of

Wrought iron into cast iron	multiply by	0.928
" " " steel	" "	1.014
" " " zinc	" "	0.918
" " " brass	" "	1.082
" " " copper	" "	1.144
" " " lead	" "	1.468

Specific Gravities

Cast iron	Average	7.21
Wrought iron	"	7.18
Cast steel	"	7.85
Bessemer steel	"	7.86

Metals

Weight of a Superficial Foot

(Jones & Laughlin)

Thickness Inch	W. Iron Lbs.	C. Iron Lbs.	Steel Lbs.	Copper Lbs.	Brass Lbs.	Lead Lbs.	Zinc Lbs.
1/16	2.53	2.34	2.55	2.89	2.73	3.71	2.34
1/8	5.05	4.69	5.10	5.78	5.47	7.42	4.69
3/16	7.58	7.03	7.66	8.67	8.20	11.13	7.03
1/4	10.10	9.38	10.21	11.56	10.94	14.83	9.38
5/16	12.63	11.72	12.76	14.45	13.67	18.54	11.72
3/8	15.16	14.06	15.31	17.34	16.41	22.25	14.06
7/16	17.68	16.41	17.87	20.23	19.14	25.96	16.41
1/2	20.21	18.75	20.42	23.13	21.88	29.67	18.75
5/8	25.27	23.44	25.52	28.91	27.34	37.08	23.44
3/4	30.31	28.13	30.63	30.69	32.81	44.50	28.13
7/8	35.37	32.81	35.73	40.47	38.28	51.92	32.81
1	40.42	37.50	40.83	46.25	43.75	59.33	37.50

Color Effect of Heat on Iron

(Pouillet)

°Cent.	°Fahr.	
210	410	Pale yellow.
221	430	Dull yellow.
256	493	Crimson.
261 370	502 680	Violet, purple and dull blue; between 261 and 370 C. it passes to bright blue, to sea green and then disappears.
500	932	Commences to be covered with a light coating of oxide; loses a good deal of its hardness; becomes a good deal more impressible to the hammer, and can be twisted with ease.
525	977	Becomes nascent red.
700	1292	Sombre red.
800	1472	Nascent cherry.
900	1657	Cherry.
1000	1832	Bright cherry.
1100	2012	Dull orange.
1200	2192	Bright orange.
1300	2372	White.
1400	2552	Brilliant white, welding heat.
1500 1600	2732 2912	Dazzling white.

Tempering of Steel

Colors Corresponding to Temperatures

(Haswell)

°Cent.	°Fahr.		°Cent.	°Fahr.	
221	430	Faint yellow.	304	580	Polish blue.
233	460	Straw color.	316	600	Dark blue.
243	470	Dark straw.	400	752	Bright red in the dark.
277	530	Purple.	474	884	Red hot in twilight.
289	550	Blue.	581	1077	Red, visible by day.
293	560	Full blue.			

Tempering of Tools

(Rose and Kent)

Following list of tools is arranged in the order of the color scale as it appears on bright steel when heated in air:

Scrapers for brass.	Very pale yellow.
Steel engraving tools.	430° F.
Slight-turning tools	
Hammer faces.	
Planer tools for steel.	
Ivory-cutting tools.	
Planer tools for iron.	
Paper cutters.	
Wood-engraving tools.	
Bone-cutting tools.	
Milling cutters.	Straw yellow.
Wire-drawing dies.	460° F.
Boring cutters.	
Leather-cutting dies.	
Screw-cutting dies.	
Inserted saw teeth.	
Taps.	
Rock drills.	
Chasers.	
Punches and dies.	
Penknives.	
Reamers.	
Half-round bits.	
Planing and moulding cutters.	Brown yellow, 500° F.
Stone-cutting tools.	
Gauges.	
Hand plane irons.	
Twist drills.	
Flat drills for brass.	
Wood-boring cutters.	
Drifts.	
Coppersmith's tools.	Light purple,
Edging cutters.	530° F.
Augers.	
Dental and surgical instruments.	
Cold chisels for steel.	Dark purple,
Axes.	550° F.
Gimlets.	
Cold chisels for cast iron.	
Saws for bone and ivory.	
Needles.	
Firmer chisels.	
Hack saws.	
Framing chisels.	
Cold chisels for wrought iron.	
Moulding and planing cutters.	
Circular saws for metals.	
Screw drivers.	
Springs.	
Saws for wood.	Dark blue, 570° F.
	Pale blue, 610° F.
	Blue-green, 630° F.

Suitable Temperatures for

Annealing steel	900–1300° F.
" malleable iron (furnace iron)	1200–1400 F.
" " " (cupola iron)	1500–1700 F.
" glass (initial temperature)	950 F.
Working "	1200–1475 F.
Melting " (into a fluid)	2200 F.
Hardening tool steel	1200–1400 F.
Case-hardening iron and soft steel	1300–1500 F.
Core ovens in foundries	350 F.
Drying kilns for wood	300 F.
Baking white enamel, Bicycle paint,	150 F.
" red and green enamel, Bicycle paint,	250 F.
" black enamel, Bicycle paint,	300 F.
Vulcanizing rubber	295 F.
Galvanizing	800 F.
Tinning	500 F.
Burning pottery	2350 F.
" brick	1800 F.
" fire brick	2450 F.

Melting-Points of Lead

(KENT)

Tin Alloys

	°Cent.	°Fahr.		°Cent.	°Fahr.
1 Tin, 25 Lead	292	558	1½ Tin, 1 Lead.............	168	334
1 " 10 "	283	541	2 " 1 " fine solder...	171	340
1 " 5 "	266	511	3 " 1 "	180	356
1 " 3 "	250	482	4 " 1 "	185	365
1 " 2 " cheap solder..	227	441	5 " 1 "	192	378
1 " 1 " c'mm'n solder	188	370	6 " 1 "	194	381

Melting-Points of Solders

(KENT)

Description	PARTS									Melting-Points
	Tin	Lead	Gold	Silver	Copper	Brass	Zinc	Nickel	Bismuth	
Common solder	1	1	...	...	.....	...	...	.....	...	......188° C., 370° F.
Fine solder....	2	1	...	...	.....	...	...	.....	...	......171 " 340 "
Cheap solder ..	1	2	...	...	.....	...	...	.....	...	......227 " 441 "
Gold solder ...	....	...	14	6	4	...	...	.....	...	
Gold solder, for 14-carat gold.	....	...	25	25	.....	12½	1	.....	...	
Silver solder...	11½	...	...	...	.....	70	7	.....	...	Undetermined
" " ...	....	...	...	145	.....	73	4	.....	...	
German S. solder......	....	...	...	...	38	54	...	8	...	
Novel's solder for Aluminum	100	5	...	...	.....	...	...	.....	...	280–300° C., 536–572 F.
	100	...	...	...	.....	5	...	.....	...	280–300 " 536–572 "
	1000	...	...	...	10–15	...	...	.....	...	350–450 " 662–842 "
	1000	...	...	...	.....	...	...	10–15	...	350–450 " 662–842 "
Novel's solder for Aluminum bronze.......	900	...	...	...	100	...	...	.....	2–3	Undetermined

Melting-Point of Fusible Plugs

(HASWELL)

2 Tin, 2 Lead......Soften at 185° C. = 365° F., melt at 189° C. = 372° F.
2 " 6 " ...... " 189 " 372 " " 195 " 383 "
2 " 7 " ...... " 192 " 377½ " " 197 " 388 "
2 " 8 " ...... " 202 " 395½ " " 209 " 408 "

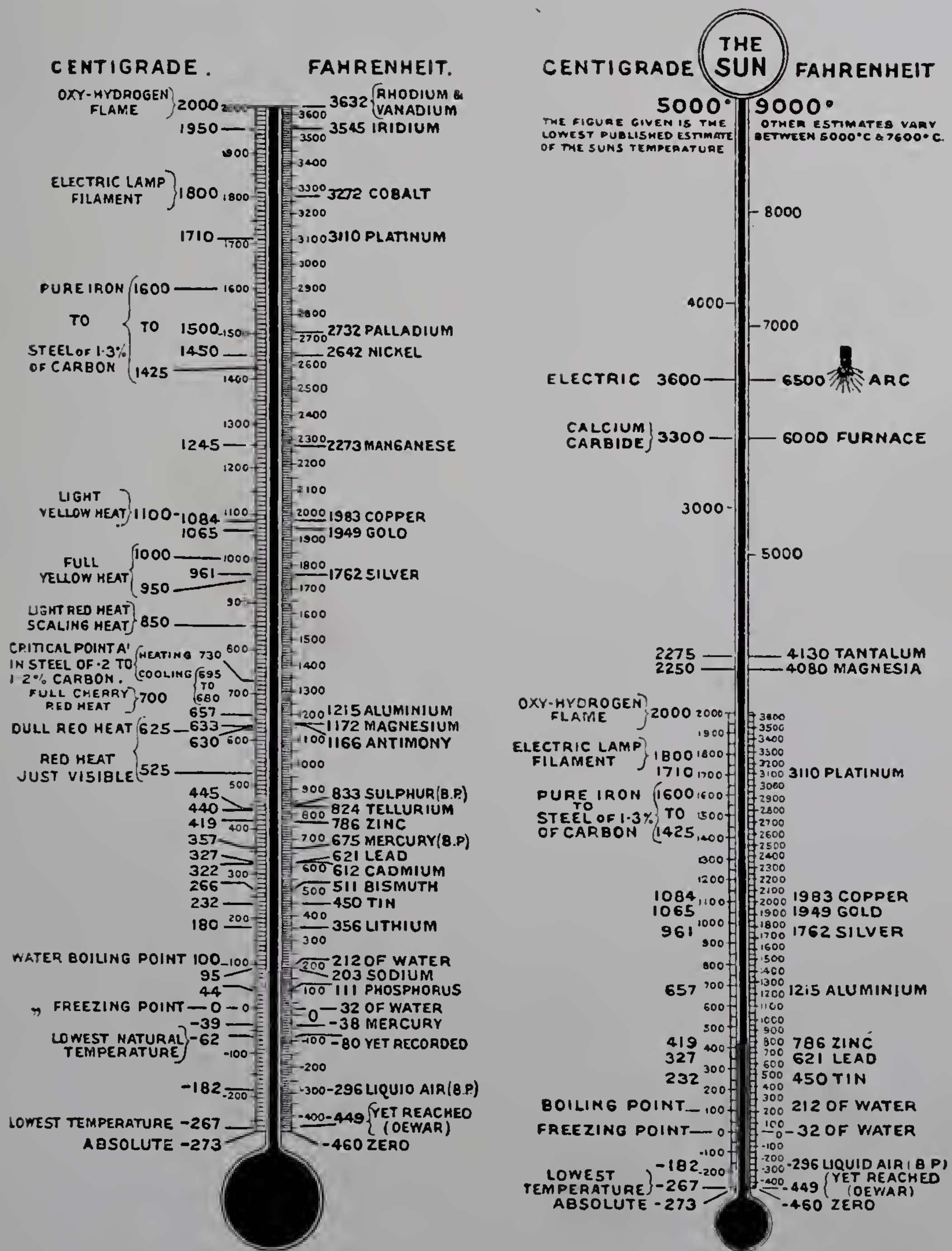
Fusing-Point and Character of Metals

(By Dr. Jules Ohly, Denver, Col.)

Metals	Melts °Fahr.	Specific Gravity	Color	Character	Elec. Cond. Silver 100	Value per Oz.	Lbs. Weight per Cu. In.
Aluminium...	1157	2.56	Blue white ..	Malleable	63.00	$ 0.03	.0924
Antimony....	842	6.71	Blue white ..	Brittle ...	3.59	.01	.2424
Arsenic	Vaporizes	5.67	Steel gray ..	Brittle ...	4.90	.05	.2048
Barium	2192	3.75	Pale yellow .	Malleable	30.61	32.00	.1355
Bismuth	485	9.80	Gray white..	Brittle ...	1.40	.10	.3540
Boron	4500	2.68	Olive green .	Hard	....	16.73	.067
Cadmium	576	8.60	Tin white ...	Malleable	24.38	.12	.3107
Cæsium	78.8	1.88	Tin white ...	Soft......	20.00	30.00	.0679
Calcium	1472	1.57	Yellow......	Malleable	21.77	.50	.0567
Cerium	1246	6.68	White	Malleable	15.75	40.00	.2413
Chromium ...	4000	6.80	Gray white..	Brittle ...	16.00	.05	.2457
Cobalt	2932	8.50	Pink white ..	Malleable	16.93	.10	.3071
Copper	1029	8.82	Pink red	Malleable	97.61	.01	.3186
Didymium ...	1346	6.54	Gray	Malleable	4.32	72.00	.2363
Erbium	1223	4.97	Dark gray ..	Malleable	31.50	62.00	.1794
Gallium......	86.1	5.90	Silver white.	Malleable	34.51	200.00	.2130
Germanium ..	1678	5.47	Gray white..	Brittle ...	15.07	95.00	.1975
Glucinum	1798	1.70	Silver white.	Malleable	31.13	80.00	.0748
Gold.........	1913	19.32	Yellow......	Malleable	76.61	20.00	.6979
Indium	349	7.42	White	Malleable	26.98	72.00	.2681
Iridium	3217	22.42	White	Malleable	13.52	10.00	.8099
Iron, pure....	2912	7.02	White	Malleable	14.57	0.$\frac{1}{32}$	.2840
Lanthanum ..	1318	6.20	White	Malleable	47.07	80.00	.2240
Lead	618	11.37	Blue white ..	Soft......	8.42	.¼	.4108
Lithium	356	0.59	White	Malleable	18.68	64.00	.0213
Magnesium ..	1200	1.74	Blue white ..	Malleable	39.44	.18	.0629
Manganese ..	3452	8.00	Gray white..	Brittle ...	15.75	.07	.2890
Mercury	39	13.59	Blue white ..	Fluid	1.75	.03	.4909
Molybdenum.	4000	8.80	Silver white .	Brittle ...	17.60	.08	.3107
Nickel	2912	8.80	Yellow white	Malleable	12.89	.03	.3179
Niobium	3978	6.27	Steel gray...	Malleable	5.13	109.72	.2265
Osmium	4532	22.48	White blue .	Malleable	13.98	23.53	.8121
Palladium....	2732	11.50	White	Malleable	12.00	8.00	.4100
Platinum	3227	21.50	White	Malleable	14.43	25.00	.7767
Potassium....	144	0.87	Blue white ..	Soft......	19.62	.20	.0314
Rhodium	3632	12.10	White	Brittle ...	12.61	40.00	.4371
Rubidium....	101	1.52	White	Soft......	20.46	88.00	.0549
Ruthenium ..	3272	12.26	White	Brittle ...	13.22	55.00	.4429
Silver........	1733	10.53	White	Malleable	1.00	.65	.3805
Silicum	3118	2.33	Gray black..	Brittle ...	.04	2.02	.0841
Sodium	194	0.97	Blue white ..	Soft......	31.98	.20	.0350
Strontium	1472	2.58	Pale yellow .	Malleable	6.60	40.00	.0918
Steel	2532	7.85	White	Malleable	12.00	.½	.2837
Tantalum	4300	10.80	Steel gray ..	Malleable	54.63	101.21	.3902
Tellurium....	977	6.25	White	Brittle ...	.0007	5.00	.2250
Thallium	550	11.85	White	Soft......	9.13	40.00	.4281
Thorium	1100	11.10	White	Brittle ...	8.60	160.00	.4000
Tin	446	7.29	Silver white .	Malleable	14.39	.02	.2634
Titanium	4400	5.30	Iron gray ...	Malleable	13.73	50.00	.1915
Tungsten	4000	17.60	White	Brittle ...	14.00	.04	.6900
Uranium.....	1650	18.70	Steel white..	Malleable	16.47	75.00	.6755
Vanadium ...	4278	5.50	Silver white.	Malleable	4.95	80.00	.1987
Yttrium......	1250	......	Yellow white	Brittle ...	30.11	94.41	.2047
Zinc	779	7.15	Blue white ..	Malleable	29.57	.¼	.2479
Zirconium ...	3000	4.15	Gray white..	Brittle ...	.05	40.00	.1499

Temperature Chart

Illustrating an exaggerated thermometer scale on which is shown the principal melting and freezing points and other important metallurgical temperatures.



Courtesy of the "Industrial World"

Workshop Recipes

Parting Sand

Burnt sand scraped from the surface of castings.

Loam

Mixture of brick, clay and old foundry sand.

Blacking for Moulds

Charcoal powder; or, in some instances, fine coal dust.

Black Wash

Charcoal, plumbago and size.

Mixture for Welding Steel

1 sal-amoniac.
10 borax.

Pounded together and fused until clear, when it is poured out, and, after cooling, reduced to powder.

Rust-Joint Cement
(Quickly Setting)

1 sal-amoniac in powder (by weight).
2 flour of sulphur.
80 iron borings, made to a paste with water.

Rust-Joint Cement
(Slowly Setting)

2 sal-amoniac.
1 flour of sulphur.
200 iron borings.

The latter cement is the best if the joint is not required for immediate use.

Red-Lead Cement for Faced-Joints

1 white lead.
1 red lead, mixed with linseed oil to the proper consistency.

Case-Hardening

Place horn, hoof, bone-dust, or shreds of leather together with the article to be case-hardened, in an iron box subject to a blood red heat, then immerse the article in cold water.

Case-Hardening with Prussiate of Potash

Heat the article after polishing to a bright red, rub the surface over with prussiate of potash, allow it to cool to dull red, and immerse it in water.

Case-Hardening Mixtures

3 prussiate of potash.
1 sal-amoniac,
or
1 prussiate of potash.
2 sal-amoniac.
2 bone dust.

Fluxes for Soldering or Welding

Iron or steel	Borax or sal-amoniac.
Tin iron	Resin or chloride of zinc.
Copper and brass	Sal-amoniac or chloride of zinc.
Zinc	Chloride of zinc.
Lead	Tallow or resin.
Lead and tin pipes	Resin and sweet oil.

Brazing

The edges filed or scraped clean and bright, covered with spelter and powdered borax, and exposed in a clear fire to a heat sufficient to melt the solder.

Glue Cement to Resist Moisture

1 glue	Mixed with least possible quantity of water.
1 black resin	
¼ red ochre, or	
4 of glue or 1 oxide of iron	
1 of boiled oil (by weight)	

Glue to Resist Moisture

One pound of glue melted in two quarts of skimmed milk.

Marine Glue

One of Indian rubber, 12 of mineral naphtha, or coal tar. Heat gently, mix, and add plenty of powdered shellac. Pour out on a slab to cool. When used, to be heated to about 250°.

A Solvent for Rust. It is often very difficult and sometimes impossible to remove rust from articles made of iron. Those which are most thickly coated are most easily cleaned by being immersed in a solution, until saturated, of chloride of tin. The length of time they remain in this bath is determined by the thickness of the coating of rust. Generally 12 to 24 hours is long enough. The solution ought not to contain a great excess of acid, if the iron itself be not attacked. On taking them from the bath the articles are rinsed, first in water, then in ammonia, and quickly dried. The iron, when thus treated, has the appearance of dull silver. A simple polishing gives it its normal appearance.

To Remove Rust from Steel. Brush the rusted steel with a paste composed of one-half ounce of cyanide of potassium, one-half ounce castile soap, one ounce whiting, and enough water to make a paste. Then wash the steel in a solution of one-half ounce cyanide of potassium in two ounces of water.

To Preserve Steel from Rust. One caoutchouc, sixteen turpentine. Dissolve with a gentle heat, then add eight parts boiled oil. Mix by bringing them to the heat of boiling water; apply to the steel with a brush, in the way of varnish. It may be removed with turpentine.

To Clean Brass. One Roche alum and 16 water. Mix. The articles to be cleaned must be made warm, then rubbed with the above mixture, and finished with fine tripoli.

To Make Tight Steam Joints, Etc. Take white lead ground in oil, incorporate as much manganese (black oxide) as possible, adding a small portion of litharge. Knead it with the hand, dusting the board with red lead. The mass is made into a small roll and laid on the plate, first oiling the plate with linseed oil. It then can be screwed and pressed into position.

The Screw and Its Power

(KENT)

The screw is an inclined plane wrapped around a cylinder in such a way that the height of the plane is parallel to the axis of the cylinder. If the screw is formed upon the internal surface of a hollow cylinder, it is usually called a nut. When force is applied to raise a weight or overcome a resistance by means of a screw and nut, either the screw or the nut may be fixed, the other being movable. The force is generally applied at the end of a wrench or lever-arm, or at the circumference of a wheel. If $r =$ radius of the wheel or lever-arm, and $p =$ pitch of the screw, or distance between threads that is, the height of the inclined plane, for one revolution of the screw, $P =$ the applied force, and $W =$ the resistance overcome, then, neglecting resistance due to friction, $2 \times P = Wp$; $W = 6.283\ Pr \div p$. The ratio of P to W is thus independent of the diameter of the screw. In actual screws, much of the power transmitted is lost through friction.

Decimals of an Inch for each 1-64th

Fraction	Decimal	Fraction	Decimal
$\frac{1}{64}$	.015625	$\frac{33}{64}$	.515625
$\frac{1}{32}$	.03125	$\frac{17}{32}$	.53125
$\frac{3}{64}$	.046875	$\frac{35}{64}$	.546875
$\frac{1}{16}$	.0625	$\frac{9}{16}$	.5625
$\frac{5}{64}$	.078125	$\frac{37}{64}$	.578125
$\frac{3}{32}$	.09375	$\frac{19}{32}$	.59375
$\frac{7}{64}$	.109375	$\frac{39}{64}$	.609375
$\frac{1}{8}$	.125	$\frac{5}{8}$	.625
$\frac{9}{64}$	.140625	$\frac{41}{64}$	.640625
$\frac{5}{32}$	.15625	$\frac{21}{32}$	.65625
$\frac{11}{64}$	.171875	$\frac{43}{64}$	.671875
$\frac{3}{16}$	.1875	$\frac{11}{16}$	.6875
$\frac{13}{64}$	.203125	$\frac{45}{64}$	.703125
$\frac{7}{32}$	.21875	$\frac{23}{32}$	.71875
$\frac{15}{64}$	.234375	$\frac{47}{64}$	.734375
$\frac{1}{4}$	.250	$\frac{3}{4}$	.75
$\frac{17}{64}$	.265625	$\frac{49}{64}$	.765625
$\frac{9}{32}$	.28125	$\frac{25}{32}$	.78125
$\frac{19}{64}$	.296875	$\frac{51}{64}$	.796875
$\frac{5}{16}$	.3125	$\frac{13}{16}$	.8125
$\frac{21}{64}$	.328125	$\frac{53}{64}$	.828125
$\frac{11}{32}$	.34375	$\frac{27}{32}$	.84375
$\frac{23}{64}$	.359375	$\frac{55}{64}$	.859375
$\frac{3}{8}$	.375	$\frac{7}{8}$	.875
$\frac{25}{64}$	.390625	$\frac{57}{64}$	.890625
$\frac{13}{32}$	.40625	$\frac{29}{32}$	.90625
$\frac{27}{64}$	.421875	$\frac{59}{64}$	.921875
$\frac{7}{16}$	.4375	$\frac{15}{16}$	.9375
$\frac{29}{64}$	.453125	$\frac{61}{64}$	.953125
$\frac{15}{32}$	.46875	$\frac{31}{32}$	.96875
$\frac{31}{64}$	.484375	$\frac{63}{64}$	.984375
$\frac{1}{2}$	.500	1	.1

Screw-Threads, Sellers or U. S. Standard

In 1864 a committee of the Franklin Institute recommended the adoption of the system of screw-heads and bolts which was devised by Mr. William Sellers, of Philadelphia. This same system was subsequently adopted as the standard by both the Army and Navy Departments of the United States and by the Master Mechanics' and Master Car Builders' Associations, so that it may now be regarded, and in fact is called, the United States Standard.

The rule given by Mr. Sellers for proportioning the thread is as follows: Divide the pitch, or what is the same thing, the side of the thread, into eight equal parts; take off one part from the top and fill in one part in the bottom of the thread; then the flat top and bottom will equal one-eighth of the pitch, the wearing surface will be three-quarters of the pitch and the diameter of screw at bottom of thread will be expressed by the formulas.

$$\text{Diameter of bolt} = \frac{1.299}{\text{No. threads per inch.}}$$

For a sharp V thread with angle of 60° the formula is

$$\text{Diameter of bolt} = \frac{1.733}{\text{No. of threads per inch.}}$$

The angle of the thread in the Sellers system is 60°. In the Whitworth or English system, it is 55°, and the point and root of the thread are rounded.

U. S. Standard Threads and Nuts

Short Diam. of Nuts	Long Diam. Hexigon Nuts	Long Diam. Sq. Nuts	Thickness of Nuts	Diam. of Screw	Threads per Inch	Diam. at Root of Thread	Area of Bolt at Root of Thread
1/2	37/64	7/16	1/4	1/4	20	.185	.026
19/32	11/16	10/12	5/16	5/16	18	.240	.045
11/16	51/64	63/64	3/8	3/8	16	.294	.067
25/32	7/8	1 7/64	7/16	7/16	14	.344	.092
7/8	1	1 15/64	1/2	1/2	13	.400	.125
31/32	1 1/8	1 23/64	9/16	9/16	12	.454	.161
1 1/16	1 7/32	1 1/2	5/8	5/8	11	.507	.201
1 1/4	1 7/16	1 49/64	3/4	3/4	10	.620	.301
1 7/16	1 21/32	2 1/32	7/8	7/8	9	.731	.419
1 5/8	1 7/8	2 19/64	1	1	8	.837	.550
1 13/16	2 3/32	2 9/16	1 1/8	1 1/8	7	.940	.693
2	2 5/16	2 53/64	1 1/4	1 1/4	7	1.065	.890
2 3/16	2 17/32	3 3/32	1 3/8	1 3/8	6	1.160	1.056
2 3/8	2 3/4	3 23/64	1 1/2	1 1/2	6	1.284	1.294
2 9/16	2 31/32	3 5/8	1 5/8	1 5/8	5 1/2	1.389	1.515
2 3/4	3 3/16	3 57/64	1 3/4	1 3/4	5	1.491	1.746
2 15/16	3 13/32	4 5/32	1 7/8	1 7/8	5	1.616	2.051
3 1/8	3 5/8	4 27/64	2	2	4 1/2	1.712	2.301
3 1/2	4 1/16	4 61/64	2 1/4	2 1/4	4 1/2	1.962	3.023
3 7/8	4 1/2	5 31/64	2 1/2	2 1/2	4	2.176	3.718
4 1/4	4 29/32	6	2 3/4	2 3/4	4	2.426	4,622
4 5/8	5 3/8	6 17/32	3	3	3 1/2	2.629	5.428
5	5 13/16	7 1/16	3 1/4	3 1/4	3 1/2	2.879	6.599
5 3/8	6 7/64	7 39/64	3 1/2	3 1/2	3 1/4	3.100	7.547
5 3/4	6 21/32	8 1/8	3 3/4	3 3/4	3	3.318	8.641
6 1/8	7 3/32	8 41/64	4	4	3	3.567	9.993

Different Standards

For Wire Gauge in Use in the United States

Dimensions of Sizes in Decimal Parts of an Inch

Number of Wire Gauge	American or Brown & Sharpe	Birmingham or Stub's Wire	Washburn-Moen Mfg. Co., Worcester, Mass.	Imperial Wire Gauge	Stub's Steel Wire	U. S. Standard for Plate
000000	....	....	....	.464	....	.46875
00000	....	....	....	.432	....	.4375
0000	.46	.454	.3938	.400	....	.40625
000	.40964	.425	.3625	.372	....	.375
00	.3648	.38	.3310	.348	....	.34375
0	.32486	.34	.3065	.324	....	.3125
1	.2893	.3	.2830	.300	.227	.28125
2	.25763	.284	.2625	.276	.219	.265625
3	.22942	.259	.2437	.252	.212	.25
4	.20431	.238	.2253	.232	.207	.234375
5	.18194	.22	.2070	.212	.204	.21875
6	.16202	.203	.1920	.192	.201	.203125
7	.14428	.18	.1770	.176	.199	.1875
8	.12849	.165	.1620	.160	.197	.171875
9	.11443	.148	.1483	.144	.194	.15625
10	.10189	.134	.1350	.128	.191	.140625
11	.090742	.12	.1205	.116	.188	.125
12	.080808	.109	.1055	.104	.185	.109375
13	.071961	.095	.0915	.092	.182	.09375
14	.064084	.083	.0800	.080	.180	.078125
15	.057068	.072	.0720	.072	.178	.0703125
16	.05082	.065	.0625	.064	.175	.0625
17	.045257	.058	.0540	.056	.172	.05625
18	.040303	.049	.0475	.048	.168	.05
19	.03589	.042	.0410	.040	.164	.04375
20	.031961	.035	.0348	.036	.161	.0375
21	.028462	.032	.03175	.032	.157	.034375
22	.025347	.028	.0286	.028	.155	.03125
23	.022571	.025	.0258	.024	.153	.028125
24	.0201	.022	.0230	.022	.151	.025
25	.0179	.02	.0204	.020	.148	.021875
26	.01594	.018	.0181	.018	.146	.01875
27	.014195	.016	.0173	.0164	.143	.0171875
28	.012641	.014	.0162	.0149	.139	.015625
29	.011257	.013	.0150	.0136	.134	.0140625
30	.010025	.012	.0140	.0124	.127	.0125
31	.008928	.01	.0132	.0116	.120	.0109375
32	.00795	.009	.0128	.0108	.115	.01015625
33	.00708	.008	.0118	.0100	.112	.009375
34	.006304	.007	.0104	.0092	.110	.00859375
35	.005614	.005	.0095	.0084	.108	.0078125
36	.005	.004	.0090	.0076	.106	.00703125
37	.004453	....	....	.0068	.103	.006640625
38	.003965	....	....	.0060	.101	.00625
39	.003531	....	....	.0052	.099	....
40	.003144	....	....	.0048	.097	....

Table of Circumference and Area of Circles

Diam. in Inches	Circumference in Inches	Area in Inches	Diam. in Inches	Circumference in Inches	Area in Inches	Diam. in Inches	Circumference in Inches	Area in Inches
1/4	.785	.049	13 1/2	42.411	143.14	26 3/4	84.037	562.00
1/2	1.570	.196	13 3/4	43.196	148.49	27	84.823	572.56
3/4	2.356	.441	14	43.982	153.94	27 1/4	85.608	583.21
1	3.141	.785	14 1/4	44.767	159.48	27 1/2	86.393	593.96
1 1/4	3.926	1.227	14 1/2	45.553	165.13	27 3/4	87.179	604.81
1 1/2	4.712	1.767	14 3/4	46.338	170.87	28	87.964	615.75
1 3/4	5.497	2.405	15	47.123	176.71	28 1/4	88.750	626.80
2	6.283	3.141	15 1/4	47.909	182.65	28 1/2	89.535	637.94
2 1/4	7.068	3.976	15 1/2	48.694	188.69	28 3/4	90.320	649.18
2 1/2	7.853	4.908	15 3/4	49.480	194.83	29	91.106	660.52
2 3/4	8.639	5.939	16	50.265	201.06	29 1/4	91.891	671.96
3	9.424	7.068	16 1/4	51.050	207.39	29 1/2	92.677	683.49
3 1/4	10.210	8.295	16 1/2	51.836	213.82	29 3/4	93.462	695.13
3 1/2	10.995	9.621	16 3/4	52.621	220.35	30	94.247	706.86
3 3/4	11.781	11.045	17	53.407	226.98	30 1/4	95.033	718.69
4	12.566	12.566	17 1/4	54.192	233.71	30 1/2	95.818	730.62
4 1/4	13.351	14.186	17 1/2	54.977	240.53	30 3/4	96.604	742.64
4 1/2	14.137	15.904	17 3/4	55.763	247.45	31	97.389	754.77
4 3/4	14.922	17.721	18	56.548	254.47	31 1/4	98.174	766.99
5	15.708	19.635	18 1/4	57 334	261.58	31 1/2	98.960	779.31
5 1/4	16.493	21.648	18 1/2	58.119	268.80	31 3/4	99.745	791.73
5 1/2	17.278	23.758	18 3/4	58.904	276.12	32	100.531	804.25
5 3/4	18.064	25.967	19	59.690	283.53	32 1/4	101.316	816.86
6	18.849	28.274	19 1/4	60.475	291.04	32 1/2	102.102	829.58
6 1/4	19.635	30.680	19 1/2	61.261	298.65	32 3/4	102.887	842.39
6 1/2	20.420	33.183	19 3/4	62.046	306.35	33	103.673	855.30
6 3/4	21.205	35.785	20	62.831	314.16	33 1/4	104.458	868.31
7	21.991	38.485	20 1/4	63.617	322.06	33 1/2	105.243	881.41
7 1/4	22.776	41.282	20 1/2	64.402	330.06	33 3/4	106.029	894.62
7 1/2	23.561	44.179	20 3/4	65.188	338.16	34	106.814	907.92
7 3/4	24.347	47.173	21	65.973	346.36	34 1/4	107.600	921.32
8	25.132	50.265	21 1/4	66.758	354.66	34 1/2	108.385	934.82
8 1/4	25.918	53.456	21 1/2	67.544	363.05	34 3/4	109.170	948.42
8 1/2	26.703	56.745	21 3/4	68.329	371.54	35	109.956	962.11
8 3/4	27.488	60.132	22	69.115	380.13	35 1/4	110.741	975.91
9	28.274	63.617	22 1/4	69.900	388.82	35 1/2	111.527	989.80
9 1/4	29.059	67.201	22 1/2	70.685	397.61	35 3/4	112.312	1003.8
9 1/2	29.845	70.882	22 3/4	71.471	406.49	36	113.097	1017.9
9 3/4	30.630	74.662	23	72.256	415.48	36 1/4	113.883	1032.1
10	31.415	78.540	23 1/4	73.042	424.56	36 1/2	114.668	1046.3
10 1/4	32.201	82.516	23 1/2	73.827	433.74	36 3/4	115.454	1060.7
10 1/2	32.986	86.590	23 3/4	74.612	443.01	37	116.239	1075.2
10 3/4	33.772	90.763	24	75.398	452.39	37 1/4	117.024	1089.8
11	34.557	95.033	24 1/4	76.183	461.86	37 1/2	117.810	1104.5
11 1/4	35.342	99.402	24 1/2	76.969	471.44	37 3/4	118.596	1119.2
11 1/2	36.128	103.87	24 3/4	77.754	481.11	38	119.381	1134.1
11 3/4	36.913	108.43	25	78.539	490.87	38 1/4	120.166	1149.1
12	37.699	113.10	25 1/4	79.325	500.74	38 1/2	120.951	1164.2
12 1/4	38.484	117.86	25 1/2	80.110	510.71	38 3/4	121.737	1179.3
12 1/2	39.269	122.72	25 3/4	80.896	520.77	39	122.522	1194.6
12 3/4	40.055	127.68	26	81.681	530.93	39 1/4	123.308	1210.0
13	40.840	132.73	26 1/4	82.466	541.19	39 1/2	124.093	1225.4
13 1/4	41.626	137.89	26 1/2	83.252	551.55	39 3/4	124.878	1241.0

Table of Circumference and Area of Circles—Continued

Diam. in Inches	Circumference in Inches	Area in Inches	Diam. in Inches	Circumference in Inches	Area in Inches	Diam. in Inches	Circumference in Inches	Area in Inches
40	125.664	1256.6	$53\frac{1}{4}$	167.290	2227.0	$66\frac{1}{2}$	208.916	3473.2
$40\frac{1}{4}$	126.449	1272.4	$53\frac{1}{2}$	168.075	2248.0	$66\frac{3}{4}$	209.701	3499.4
$40\frac{1}{2}$	127.235	1288.2	$53\frac{3}{4}$	168.861	2269.1	67	210.487	3525.7
$40\frac{3}{4}$	128.020	1304.2	54	169.646	2290.2	$67\frac{1}{4}$	211.272	3552.0
41	128.805	1320.3	$54\frac{1}{4}$	170.431	2311.5	$67\frac{1}{2}$	212.058	3578.5
$41\frac{1}{4}$	129.591	1336.4	$54\frac{1}{2}$	171.217	2332.8	$67\frac{3}{4}$	212.843	3605.0
$41\frac{1}{2}$	130.376	1352.7	$54\frac{3}{4}$	172.002	2354.3	68	213.628	3631.7
$41\frac{3}{4}$	131.161	1369.0	55	172.788	2375.8	$68\frac{1}{4}$	214.414	3658.4
42	131.947	1385.4	$55\frac{1}{4}$	173.573	2397.5	$68\frac{1}{2}$	215.199	3685.3
$42\frac{1}{4}$	132.732	1402.0	$55\frac{1}{2}$	174.358	2419 2	$68\frac{3}{4}$	215.984	3712.2
$42\frac{1}{2}$	133.518	1418.6	$55\frac{3}{4}$	175.144	2441.1	69	216.770	3739.3
$42\frac{3}{4}$	134.303	1435.4	56	175.929	2463.0	$69\frac{1}{4}$	217.555	3766.4
43	135.088	1452.2	$56\frac{1}{4}$	176.715	2485.0	$69\frac{1}{2}$	218.341	3793.7
$43\frac{1}{4}$	135.874	1469.1	$56\frac{1}{2}$	177.500	2507.2	$69\frac{3}{4}$	219.126	3821.0
$43\frac{1}{2}$	136.659	1486.2	$56\frac{3}{4}$	178.285	2529.4	70	219.911	3848.5
$43\frac{3}{4}$	137.445	1503.3	57	179.071	2551.8	$70\frac{1}{4}$	220.697	3876.0
44	138.230	1520.5	$57\frac{1}{4}$	179.856	2574.2	$70\frac{1}{2}$	221.482	3903.6
$44\frac{1}{4}$	139.015	1537.9	$57\frac{1}{2}$	180.642	2596.7	$70\frac{3}{4}$	222.268	3931.4
$44\frac{1}{2}$	139.801	1555.3	$57\frac{3}{4}$	181.427	2619.4	71	223.053	3959.2
$44\frac{3}{4}$	140.586	1572.8	58	182.212	2642.1	$71\frac{1}{4}$	223.838	3987.1
45	141.372	1590.4	$58\frac{1}{4}$	182.998	2664.9	$71\frac{1}{2}$	224.624	4015.2
$45\frac{1}{4}$	142.157	1608.2	$58\frac{1}{2}$	183.783	2687.8	$71\frac{3}{4}$	225.409	4043.3
$45\frac{1}{2}$	142.942	1626.0	$58\frac{3}{4}$	184.569	2710.9	72	226.195	4071.5
$45\frac{3}{4}$	143.728	1643.9	59	185.354	2734.0	$72\frac{1}{4}$	226.980	4099.8
46	144.513	1661.9	$59\frac{1}{4}$	186.139	2757.2	$72\frac{1}{2}$	227.765	4128.2
$46\frac{1}{4}$	145.299	1680.0	$59\frac{1}{2}$	186.925	2780.5	$72\frac{3}{4}$	228.551	4156.8
$46\frac{1}{2}$	146.084	1693.2	$59\frac{3}{4}$	187.710	2803.9	73	229.336	4185.4
$46\frac{3}{4}$	146.869	1716.5	60	188.496	2827.4	$73\frac{1}{4}$	230.122	4214.1
47	147.655	1734.9	$60\frac{1}{4}$	189.281	2851.0	$73\frac{1}{2}$	230.907	4242.9
$47\frac{1}{4}$	148.440	1753.5	$60\frac{1}{2}$	190.066	2874.8	$73\frac{3}{4}$	231.692	4271.8
$47\frac{1}{2}$	149.226	1772.1	$60\frac{3}{4}$	190.852	2898.6	74	232.478	4300.8
$47\frac{3}{4}$	150.011	1790.8	61	191.637	2922.5	$74\frac{1}{4}$	233.263	4329.9
48	150.796	1809.6	$61\frac{1}{4}$	192.423	2946.5	$74\frac{1}{2}$	234.049	4359.2
$48\frac{1}{4}$	151.582	1828.5	$61\frac{1}{2}$	193.208	2970.6	$74\frac{3}{4}$	234.834	4388.5
$48\frac{1}{2}$	152.367	1847.5	$61\frac{3}{4}$	193.993	2994.8	75	235.619	4417.9
$48\frac{3}{4}$	153.153	1866.5	62	194.779	3019.1	$75\frac{1}{4}$	236.405	4447.4
49	153.938	1885.7	$62\frac{1}{4}$	195.564	3043.5	$75\frac{1}{2}$	237.190	4477.0
$49\frac{1}{4}$	154.723	1905.0	$62\frac{1}{2}$	196.350	3068.0	$75\frac{3}{4}$	237.976	4506.7
$49\frac{1}{2}$	155.509	1924.4	$62\frac{3}{4}$	197.135	3092.6	76	238.761	4536.5
$49\frac{3}{4}$	156.294	1943.9	63	197.920	3117.2	$76\frac{1}{4}$	239.546	4566.4
50	157.080	1963.5	$63\frac{1}{4}$	198.706	3142.0	$76\frac{1}{2}$	240.332	4596.3
$50\frac{1}{4}$	157.865	1983.2	$63\frac{1}{2}$	199.491	3166.9	$76\frac{3}{4}$	241.117	4626.4
$50\frac{1}{2}$	158.650	2003.0	$63\frac{3}{4}$	200.277	3191.9	77	241.903	4656.6
$50\frac{3}{4}$	159.436	2022.8	64	201.062	3217.0	$77\frac{1}{4}$	242.688	4686.9
51	160.221	2042.8	$64\frac{1}{4}$	201.847	3242.2	$77\frac{1}{2}$	243.473	4717.3
$51\frac{1}{4}$	161.007	2062.9	$64\frac{1}{2}$	202.633	3267.5	$77\frac{3}{4}$	244.259	4747.8
$51\frac{1}{2}$	161.792	2083.1	$64\frac{3}{4}$	203.418	3292.8	78	245.044	4778.4
$51\frac{3}{4}$	162.577	2103.3	65	204.204	3318.3	$78\frac{1}{4}$	245.830	4809.0
52	163.363	2123.7	$65\frac{1}{4}$	204.989	3343.9	$78\frac{1}{2}$	246.615	4839.8
$52\frac{1}{4}$	164.148	2144.2	$65\frac{1}{2}$	205.774	3369.6	$78\frac{3}{4}$	247.400	4870.7
$52\frac{1}{2}$	164.934	2164.8	$65\frac{3}{4}$	206.560	3395.3	79	248.186	4901.7
$52\frac{3}{4}$	165.719	2185.4	66	207.345	3421.2	$79\frac{1}{4}$	248.971	4932.7
53	166.504	2206.2	$66\frac{1}{4}$	208.131	3447.2	$79\frac{1}{2}$	249.757	4963.9

Table of Circumference and Area of Circles—Continued

Diam. in Inches	Circumference in Inches	Area in Inches	Diam. in Inches	Circumference in Inches	Area in Inches	Diam. in Inches	Circumference in Inches	Area in Inches
79¾	250.542	4995.2	84½	265.465	5607.9	91	285.885	6503.9
80	251.327	5026.5	84¾	266.250	5641.2	91½	287.456	6575.5
80¼	252.113	5058.0	85	267.035	5674.5	92	289.027	6647.6
80½	252.898	5089.6	85¼	267.821	5707.9	92½	290.597	6720.1
80¾	253.684	5121.2	85½	268.606	5741.5	93	292.168	6792.9
81	254.469	5153.0	85¾	269.392	5775.1	93½	293.739	6866.1
81¼	255.254	5184.9	86	270.177	5808.8	94	295.310	6939.8
81½	256.040	5216.8	86¼	270.962	5842.6	94½	296.881	7013.8
81¾	256.825	5248.9	86½	271.748	5876.5	95	298.451	7088.2
82	257.611	5281.0	86¾	272.533	5910.6	95½	300.022	7163.0
82¼	258.396	5313.3	87	273.319	5944.7	96	301.593	7238.2
82½	259.181	5345.6	87¼	274.104	5978.9	96½	303.164	7313.8
82¾	259.967	5378.1	87½	274.889	6013.2	97	304.734	7389.8
83	260.752	5410.6	88	276.460	6082.1	97½	306.305	7466.2
83¼	261.538	5443.3	88½	278.031	6151.4	98	307.876	7543.0
83½	262.323	5476.0	89	279.602	6221.1	98½	309.447	7620.1
83¾	263.108	5508.8	89½	281.173	6291.2	99	311.018	7697.7
84	263 894	5541.8	90	282.743	6361.7	99½	312.588	7775.6
84¼	264.679	5574.8	90½	284.314	6432.6	100	314.159	7854.0

Case 1

For diameters greater than 100 and less than 1001:

Take from the table the area or circumference for a circle the diameter of which is one-tenth of the given diameter.

To obtain the required area or circumference, multiply the area so found by 100 and the circumference so found by 10.

For example: What is the area and circumference corresponding to a diameter of 459?

From the tables the area and circumference for diameter 45.9 are 1654.6847 and 144.1991. Therefore 165468.47 and 1441.991 are the area and circumference required.

Case 2

For diameters greater than 1000:

Divide the given diameter by any convenient factor which will give as a quotient a diameter found in the table, and take from the table the area or circumference for this diameter.

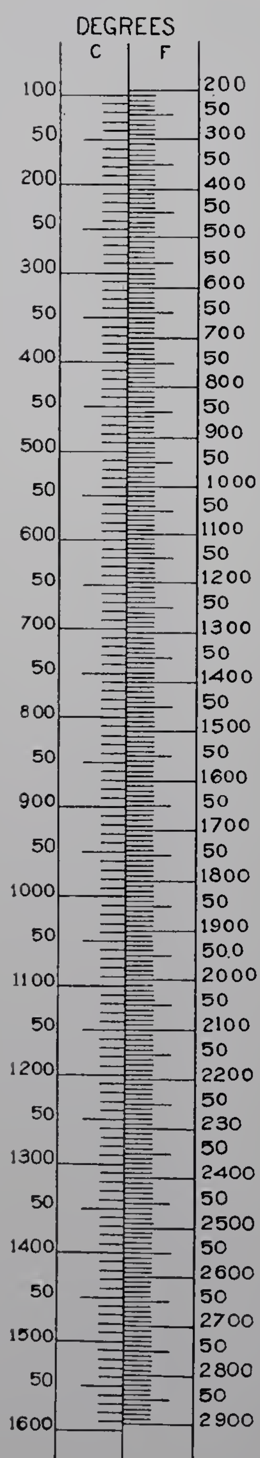
To obtain the required area or circumference, multiply the area so found by the square of the factor and the circumference so found by the factor.

For example: What is the area and circumference corresponding to a diameter of 1983?

$1983 \div 3 = 661$. From the tables and Case 1, the area and circumference for diameter 661 are 343156.95 and 2076.593. Therefore 343156.95 $\times 9 = 3088412.55$ area required, and $2076.593 \times 3 = 6229.779$ circumference required.

Thermometers

THERMOMETERS are divided into three distinct classes, the Fahrenheit, the Centigrade or Celsius, and the Reaumur. The Fahrenheit thermometer is generally used in English speaking countries, and the Centigrade or Celsius thermometers in countries that use the metric system. In many scientific tests in English, however, the Centigrade temperatures are also used, either with or without their Fahrenheit equivalents.



Comparative Scale of Degrees Celsius and Fahrenheit

FORMULA = $\frac{C \times 9}{5} + 32 = F$

In all thermometers the freezing and boiling point of water under mean atmospheric pressure at sea level are assumed at two fixed points, but the division of the scale between these two points varies in different countries; hence the above mentioned classes of thermometers. In the Fahrenheit the space between the two fixed points is divided into 180 parts; the boiling point is marked 212 and the freezing point 32, and zero is a temperature which, at the time this thermometer was invented, was incorrectly imagined to be the lowest temperature attainable. In the Centigrade and Reaumur scales the distance between the two fixed points is divided into 100 and 80 parts, respectively. In each of these two scales the freezing point is marked 0, and the boiling point is marked 100 in the Centigrade and 80 in the Reaumur. Each of the 180, 100 or 80 divisions in the respective thermometers is called a degree.

	Freezing Point	Boiling Point
Reaumur	0	80
Celsius	0	100
Fahrenheit	32	212

1 Fahrenheit degree, $= \frac{5}{9}°$ Centigrade $= \frac{4}{9}°$ Reaumur
1 Centigrade degree, $= \frac{9}{5}°$ Fahrenheit $= \frac{4}{5}°$ Reaumur
1 Reaumur degree, $= \frac{9}{4}°$ Fahrenheit $= \frac{5}{4}°$ Centigrade
Temperature Fahrenheit, $= \frac{9}{5} \times$ C. $+ 32° = \frac{9}{4}$ R. $+ 32°$
Temperature Centigrade, $= \frac{5}{9}$ (Tem.F.—32°) $= \frac{5}{4}$ R.
Temperature Reaumur, $= \frac{4}{5}$ (Tem.C.) $= \frac{4}{9}$ (F.—32°)

Simplified, the above reduces to:

To change Centigrade scale to Fahrenheit, multiply the degrees in Centigrade by 9, divide by 5, and add 32 degrees.

To change Reaumur to Fahrenheit, multiply the number of degrees Reaumur by 9, divide by 4, and add 32 degrees.

And to change Fahrenheit to Centigrade or Reaumur, simply reverse the above and the result will be obtained.

Absolute Zero

The absolute zero of a gas, is a theoretical consequence of the law of expansion by heat, assuming that it is possible to continue the cooling of a perfect gas until its volume is diminished to nothing.

In the Centigrade scale the coefficient of expansion of air per degree is 1/273; that is, its pressure being constant, the volume of a perfect gas increases 1/273 of its volume at 0°C. for every increase in temperature of 1° C. In Fahrenheit units it increases 1/491.2 of its volume at 32° F. for every increase of 1° F.

If the volume of a perfect gas increases 1/273 of its volume at 0° C. for every increase of temperature of 1° C. and decreases 1/273 of its volume for every decrease of temperature of 1° C., then at —273° C. or 491.2° F. below the melting point of ice on the air thermometer, or —492.66° F. (or —460.66°) is called the absolute zero. Absolute temperatures therefore are temperatures measured, on either the Fahrenheit or Centigrade scale, from this zero.

Power Transmission

Rules for Ascertaining Horse Power, Etc., of Shafting

SHAFTS for transmitting power are subject to two forces, viz.: transverse strain and torsion.

The torsional strength of shafts, or their resistance to breaking by twisting, is proportional to the cube of their diameter. Their stiffness, or resistance to bending, is proportional to the fourth power of their diameters, and varies inversely in proportion to their load, and also to the cube of the length of their spans or "bay."

Coefficients for Use in Following Rules:

Wrought Iron Main Shaft, hammered and turned	120
Steel " " " " "	90
Wrought Iron Line " " " "	90
Steel " " " " "	67.5
Wrought Iron Line Shaft, rolled and turned	100
Steel " " " " "	75

FORMULAS:

RULE 1. To find maximum horse power of a shaft within good working limits:

$$\frac{\text{Diameter}^3 \times \text{revolutions per minute}}{\text{Coefficient}}$$

RULE 2. To find the diameter of a shaft, capable within good working limits, of transmitting a given horse power:

$$\left.\frac{\text{Horse Power} \times \text{Coefficient}}{\text{Revolutions per minute.}}\right\} \text{The cube root of the quotient is the diameter in inches.}$$

RULE 3. To find the speed required for transmitting a given horse power within good working limits:

$$\frac{\text{Horse Power} \times \text{Coefficient}}{\text{Diameter}^3}$$

Shaft Bearings

The distance apart of shaft bearings may be obtained by the following rule, which is applicable for shafts up to 4 inches diameter. Extra bearings should be provided wherever power is taken off by main belts or gears:

$$L = 4.8 \sqrt[3]{d^2}$$

L = Length in feet between supports.
D = Diameter of shaft in inches.
For a 4-inch shaft $L = 4.8 \sqrt[3]{16} = 12$ feet.

Approximate Centers of Bearings Deduced from above Formulæ

Diameter of Shaft	Centers
1″	4 ft. 9 in.
1½″	6 " 3 "
2″	7 " 8 "
2½″	8 " 10 "
3″	10 " 0 "
3½″	11 " 1 "
4″	12 " 0 "

Pulleys

Rules for calculating the speed and sizes of pulleys:

PROBLEM 1. The diameter of the driver and driven being given, to find the number of revolutions of the driven.

RULE. Multiply the diameter of the driver by its number of revolutions, and divide the product by the diameter of the driven; the quotient will be the number of revolutions.

PROBLEM 2. The diameter and the revolutions of the driver being given, to find the diameter of the driven, that shall make any given number of revolutions in the same time.

RULE. Multiply the diameter of the driver by its number of revolutions, and divide the product by the number of the driven; the quotient will be its diameter.

PROBLEM 3. To ascertain the size of the driver.

RULE. Multiply the diameter of the driven by the number of revolutions you wish to make, and divide the product by the revolutions of the driver; the quotient will be the size of the driver.

PROBLEM 4. To find the horse power of a pulley.

RULE. Multiply the circumference of the pulley by the speed, and the product thus obtained by the width of the belt, and divide the result by 600. The quotient will be the horse power.

The above rules are practically correct. Though, owing to the slip, elasticity and thickness of the belt, the circumference of the driven seldom runs as fast as the driver.

Belts, like gears, have a pitch line, or a circumference of uniform motion. The circumference is within the thickness of the belt, and must be considered if pulleys differ greatly in diameter and a required speed is absolutely necessary.

Belting

In the practical application of rules and formulas for belting, good judgment, experience and a consideration of the conditions are the governing factors.

Operating conditions and the coefficient of friction of belts, on pulleys vary so greatly that it is advisable and customary to use arbitrary rules and formulas that have proved safe in practice.

The following notes and rules are based on modern practice and will be found thoroughly reliable for average conditions:

The power of a belt to transmit motion is derived from the friction hold on the pulley. Diminution in friction hold from any cause brings about a condition known as *slipping*. With every revolution of a pulley a portion of the power is lost; the loss varies with the condition of the belt, change of load, state of the atmosphere, etc.

Power should be communicated through the lower running side of a belt; the upper side to carry the slack.

A long belt will transmit more power than a short one of the same width and tension.

A belt under favorable conditions will deliver 97% of its efficiency.

A single belt one inch wide will transmit one horse power at 1000 feet per minute, belt speed, or 33 pounds working strain per inch of belt.

The working tension for single belts in good condition can safely be put at 45 pounds per inch of width.

The strength of a belt increases directly as its width.

Average breaking weight of a belt, 3/16 x 1 inch wide—Leather, 530 pounds; 3-ply rubber, 600 pounds.

The coefficient of safety for laced belts is—Leather, 1/16 breaking weight; rubber, ⅛ breaking weight.

Excessively tight or loose belts cause a loss of power; in the former case from friction at the journals, and in the latter from slipping.

Excessive slipping dries out the leather and reduces the adhesion.

Within reasonable limits the greater the speed the more efficient the belt. A speed of 3,000 feet per minute is a safe maximum.

A double belt will last longer than a single one, and will take double the tension, and will transmit 7/10 more power, as capacity to transmit power is governed by the frictional width of belt and its pulling strength.

A rawhide belt will transmit from 25% to 50% more power than a tanned one, and for straight non-shifting work is much the more economical. It is, however, adapted to cone pulleys or countershaft work.

Belts should be used with hair side to the pulley, as this gives greater adhesion.

The ordinary thickness of leather belts is 3/16 inch, and weighs about 60 pounds per cubic foot.

Ordinarily, 4-ply cotton belting is considered equivalent to single leather belting.

Where pulley diameters are restricted, a wide thin belt is more economical than a narrow thick one.

Rules on Belting

To Obtain Most Economical Results

For	4-ply	belts,	smallest	pulley	should	be	12	inches	diameter or over.
"	6 "	"	"	"	"	"	20	"	" "
"	8 "	"	"	"	"	"	36	"	" "
"	10 "	"	"	"	"	"	60	"	" "
"	12 "	"	"	"	"	"	96	"	" "

For belts of the same width a 6-ply will transmit 1½ times as much power as a 4-ply; an 8-ply, 1¾ times as much; a 10-ply about twice as much and a 12-ply about 2¼ times as much as a 4-ply.

To find the approximate ply of a belt of a given width required economically to transmit a given horse power at a given belt speed: Multiply the given horse power by 800, and the given width in inches by the given belt speed in feet and divide the first result by the

second. If the final result is 1 or nearly 1, a 4-ply belt is required; if $1\frac{1}{2}$, a 6-ply belt is required; if $1\frac{3}{4}$, an 8-ply is required; if 2, a 10-ply is required and if $2\frac{1}{4}$, a 12-ply is required.

To find the width of a four-ply belt, required economically to transmit a given horse power, at a given belt speed per minute: Multiply the given horse power by 800, and divide the result by the given speed.

To find the width of a six-ply required: Multiply the horse power by 533 and divide the result by the belt speed.

To find the width of an eight-ply required: Multiply the horse power by 457 and divide the result by the belt speed.

To find the width of ten-ply required: Multiply the horse power by 400 and divide the result by the belt speed.

To find the width of a twelve-ply required: Multiply the horse power by 356 and divide the result by the belt speed.

To find the length of an open belt: Add the diameter of the two pulleys together, multiply by 3 1/7, divide the product by 2, add to the result twice the distance between centres of the shafts and the product will be the required length.

Horse Power of Leather Belting

TRANSMITTED WITH SAFETY AT AN ASSURED TENSION OF 50 POUNDS PER INCH OF WIDTH FOR SINGLE BELT. 100 POUNDS FOR DOUBLE BELT

FORMULAS:

D = Diameter of pulley in feet.
R = Revolutions per minute.
W = Width of belt in inches.

$$C = \begin{cases} 50 \text{ for single belt} \\ 100 \text{ for double belt} \end{cases}$$

H. P. = Horse power transmitted.

$$\frac{D \times 3.1416 \times R \times W \times C}{33000} = \text{H. P.}$$

D = Diameter in inches.
R = Revolutions per minute.
W = Width of belt in inches.
C = 2520 = Constant.
H. P. = Horse power transmitted.

Single Belting

$$\frac{D \times R \times W}{2750} = \text{H. P.}$$

The transmitting efficiency of double belts of average thickness is to that of single belts as 10 is to 7; hence the formulas for double belting would be:—

Double Belting

$$\frac{D \times R \times W}{1925} = \text{H. P.}$$

The horse power to be transmitted, and diameter of pulley being given, to find the width of belt required:—

Single Belt

$$W = \frac{\text{H. P.} \times 2750}{D \times R}$$

Double Belt

$$W = \frac{\text{H. P.} \times 1925}{D \times R}$$

The horse power and width of belt being given, to find the diameter of pulleys:—

Single Belt

$$P = \frac{\text{H. P.} \times 2750}{R \times W}$$

Double Belt

$$D = \frac{\text{H. P.} \times 1925}{R \times W}$$

The horse power, diameter of the pulley and width of belt being given, to find the number of revolutions necessary:—

Single Belt

$$R = \frac{\text{H. P.} \times 2750}{D \times W}$$

Double Belt

$$R = \frac{\text{H. P.} \times 1925}{D \times W}$$

In formulating the foregoing rules, it has been assumed that the belts are run about horizontal, and that the arc of contact is the semi-circumference. Any reduction in the arc of contact will necessitate a proportionate reduction of the tabulated horse power. If, however, the pulleys are of different diameters, and the arc of contact is less than the semi-circumference, the rules must be modified accordingly.

For open belts and pulleys of different diameters, the arc of contact is less than 180° on the smaller pulley, and a different constant, to be taken from the following table, must be substituted in the foregoing formulas.

Measure the length of the arc of contact on the smaller pulley, and divide it by the circumference of the pulley. Find the fraction in the second column which corresponds nearest to this result, and opposite this, its corresponding constant.

Degrees	Fraction of Circumference	Ratio	Single Belt Constant	Double Belt Constant
90	¼ = .25	2.21	6080	4250
112½	5/16 = .3125	1.72	4730	3310
120	⅓ = .3333	1.6	4400	3080
135	⅜ = .375	1.4	3850	2700
150	5/12 = .4167	1.24	3410	2390
157½	7/16 = .4375	1.17	3220	2250
180 to 270	½ to ¾ = .5 to .75	1.	2750	1925

If the belt is crossed and the arc of contact is greater than the semi-circumference, of course more power could be transmitted by the pulley; but only by increasing the tension so as to overtax the belt.

By multiplying the constant for the semi-circumference, by the ratios of friction and pressure given in the third column of above table, the constants for every case likely to occur in practice are obtained.

Table Giving Horse Power Transmission by Belts When the Speed and Width of Belt are Given

Speed in Feet Per Minute	Width of Belt in Inches											
	2 H. P.	3 H. P.	4 H. P.	5 H. P.	6 H. P.	8 H. P.	10 H. P.	12 H. P.	14 H. P.	16 H. P.	18 H. P.	20 H. P.
400	1	1½	2	2½	3	4	5	6	7	8	9	10
600	1½	2¼	3	3¾	4½	6	7½	9	10½	12	13½	15
800	2½	3	4	5	6	8	10	12	14	16	18	20
1000	2	3¾	5	6¼	7½	10	12½	15	17½	20	22½	25
1200	3	4½	6	7½	9	12	15	18	21	24	27	30
1500	3¾	5¾	7½	9½	11½	15	18¾	22½	26½	30	33¾	37½
1800	4½	6¾	9	11¼	13½	18	22½	27	31½	36	40½	45
2000	5	7½	10	12¼	15	20	25	30	35	40	45	50
2400	6	9	12	15	18	24	30	36	42	48	54	60
2800	7	10½	14	17½	21	28	35	42	49	56	63	70
3000	7½	11¼	15	18¾	22½	30	37½	45	52½	60	67½	75
3500	8¾	13	17½	22	26	35	44	52½	61	70	79	88
4000	10	15	20	25	30	40	50	60	70	80	90	100
4500	11¼	17	22⅔	28	34	45	57	69	78	90	102	114
5000	12½	19	25	31	37½	50	62½	75	87½	100	112	125

To find the speed in feet per minute, multiply the circumference of pulley in feet by the number of revolutions.

Gearing

In general the term "gearing" is applied to all parts of machinery by which motion is transmitted; especially is it employed for wheels whether friction or tooth. Tooth wheels, are "in gear" when their teeth are engaged together; "out of gear" when separated.

Spur Gears are wheels with the teeth or cogs ranged round the outer or inner surface of the rim, in the direction of the radii from the centre, and their action may be regarded as that of two cylinders rolling upon one another.

Bevel Gears are wheels, the teeth of which are placed upon the outer periphery in a direction verging to the apex of a cone and their action is similar to that of two cones rolling upon each other. When two bevel gears of same diameter work together at an angle of 45° they are called Mitre Wheels.

The teeth are called "teeth" when they are of one and the same piece as the body of the wheel, and "cogs" when they are of separate material. Wheels in whose rim "cogs" are inserted are called Mortise Wheels.

The straight line drawn from centre to centre of a pair of wheels is called the "line of centres."

The pitch-line, by which the size of a wheel is always given, represents, as noted above, the touching of two cylinders rolling upon one another, and is the line or circle on which the pitch of teeth is measured.

The pitch is the distance between the centres of two adjacent teeth measured at the pitch line.

The circular pitch of a gear wheel is the distance in inches measured on the pitch circle from the centre of one tooth to the centre of the next tooth.

If the distance of the teeth of a gear thus measured were 2½ inches we would say that the circular pitch was 2½ inches.

Let P = Circular pitch.
D = Diameter of pitch circle in inches.
C = Circumference of pitch circle in inches.
N = Number of teeth.
n = 3.1416.

$$P = \frac{C}{N} \text{ or } \frac{nD}{N} \qquad N = \frac{C}{P} \text{ or } \frac{nD}{P}$$

$$C = P\,N \text{ or } nD \qquad D = \frac{PN}{n} \text{ or } \frac{C}{n}$$

$$\text{Addendum} = .3\,P \qquad \text{Root} = .4\,P$$

Thickness of teeth for cut gear = .5 P; for cast gear .48 P.

The diametral pitch of a gear wheel is the number of teeth in the wheel divided by the diameter of the pitch circle in inches, or, it is the number of teeth on the circumference of the gear wheel for one inch diameter of pitch circle.

A gear with a pitch diameter of 5 inches and having 40 teeth, is 8 pitch; one with the same pitch diameter and having 70 teeth, is 14 pitch.

In the gear of 8 pitch there are 8 teeth on the circumference for each inch of the diameter of the pitch circle; and in one of 14 pitch there are 14 teeth on the circumference for each inch of the diameter of the pitch circle.

Let P = Diametral Pitch.
D = Diameter of pitch circle in inches.
N = Number of teeth.
d = Outside diameter.
L = Length of tooth.
t = Thickness of tooth.

$$P = \frac{N}{D} \qquad D = \frac{N}{P} \qquad N = P.\,D. \qquad d = \frac{N\,2}{P} \qquad L = \frac{2.157}{P} \qquad t = \frac{1.57}{P}$$

The circular pitch corresponding to any diametral pitch may be found by dividing 3.1416 by the diametral pitch; and the diametral pitch corresponding to any circular pitch may be found by dividing 3.1416 by the circular pitch.

(a) If the diametral pitch of a gear is six, what is the corresponding circular pitch?

(b) If the circular pitch is 1.5708 inches, what is the corresponding diametral pitch?

(a) $\frac{3.1416}{6} = .5236$ inches (b) $\frac{3.1416}{1.5708} = 2$

Diametral Pitches with their Corresponding Circular Pitches

Diametral Pitch or Teeth Per Inch in Diameter	Corresponding Circular Pitch	Diametral Pitch or Teeth Per Inch in Diameter	Corresponding Circular Pitch
1	3.1416	8	.3927
2	1.5708	9	.3491
3	1.0472	10	.3142
4	.7854	12	.2618
5	.6283	14	.2244
6	.5236	16	.1963
7	.4488	20	.1571

To find the horse power of spur gearing made of good cast iron:

$$\frac{P \times F \times D \times R}{600} = H.\,P.$$

Where P = Pitch of wheel in inches.
F = Face in inches.
D = Diameter in inches.
R = Revolutions per minute.

Electricity

Electrical Units

Volt: The unit of electrical motive force. Force required to send one ampere of current through one ohm of resistance.

Ohm: Unit of resistance. The resistance offered to the passage of one ampere, when impelled by one volt.

Ampere: Unit of current. The current which one volt can send through a resistance of one ohm.

Coulomb: Unit of quantity. Quantity of current which, impelled by one volt, would pass through one ohm in one second.

Farad: Unit of capacity. A conductor or condenser which will hold one coulomb under the pressure of one volt.

Joule: Unit of work. The work done by one watt in one second.

Watt: The unit of electrical energy, and is the product of ampere and volt. That is, one ampere of current flowing under a pressure of one volt gives one watt of energy.

Useful Rules for Simple Electrical Calculations

One electrical horse power is equal to 746 watts.

One Kilowatt is equal to 1,000 watts.

To find the watts consumed in a given electrical circuit, such as a lamp, multiply the volts by the amperes.

To find the volts, divide the watts by the amperes.

To find the amperes, divide the watts by the volts.

To find the electrical horse power required by a lamp, divide the watts of the lamp by 746.

To find the number of lamps that can be supplied by one electrical horse power of energy, divide 746 by the watts of the lamp.

To find the electrical horse power necessary, multiply the watts per lamp by the number of lamps and divide by 746.

To find the mechanical horse power necessary to generate the required electrical horse power, divide the latter by the efficiency of the generator.

To find the amperes of a given circuit, of which the volts and ohms resistance are known, divide the volts by the ohms.

To find the volts, when the amperes and watts are known, multiply the amperes by the ohms.

To find the resistance in ohms, when the volts and amperes are known, divide the volts by the amperes.

Equivalents of Electrical Units

(Hering)

1 Kilowatt = 1000 Watts.
1 Kilowatt = 1.34 horse power.
1 Kilowatt = 44257 foot pounds per minute.
1 Kilowatt = 56.87 B. T. U. per minute.
1 Horse power = 746 Watts.
1 Horse power = 33,000 foot pounds per minute.
1 Horse power = 42.41 B. T. U. per minute.
1 B. T. U. (British Thermal Unit) = 778 foot pounds.
1 B. T. U. = 0.2930 Watt-hours.

Relation of Speed, Alternations and Number of Poles in A. C. Generators

Alternations per minute = Number of Poles and revolutions per minute.
Cycles per second = Alternations per minute divided by 120.

Air

Useful Notes

Pertaining to Blowers, Fans and Compressors

AIR is a mechanical mixture of the gases oxygen and nitrogen; 20.7 parts oxygen and 79.3 parts nitrogen by volume, 23 parts oxygen and 77 parts nitrogen by weight.

The weight of pure air at 32° F. and a barometric pressure of 29.92 inches of mercury, or 14.6963 pounds per square inch is .080728 pounds per cubic foot.

Volume of one pound 12.387 cubic feet. At any other temperature and barometric pressure its weight in pounds per cubic foot is:

$$W = \frac{1.3253 \times B.}{459.2 + T.}$$

Where B = Height of barometric.
T = Temperature Fahrenheit.

If both the temperature and pressure vary, the weight of a cubic foot of air is found by dividing the absolute pressure by the absolute temperature multiplied by 2.7093.

Specific heat of air is .2377, or nearly one-fourth that of water. In reheating compressed air one pound of coal will produce one horse power.

Compressed air, under a pressure of 75 pounds in the receiver, will flow into the atmosphere at a velocity of 658 feet a second. The variation is so slight under different pressures, that this velocity can be used for all calculations between 30 and 100 pounds gauge.

The friction loss in transmitting air is nearly as the square of the velocity and directly as the length of the line.

In a three-inch pipe line 2,500 feet long, the maximum velocity should not exceed 1,500 feet per minute, when the pressure at the inlet is less than 100 pounds. If the line is 7,000 feet long, the velocity should not exceed 1,000 feet per minute, when the pressure at the inlet is less than 100 pounds.

In a six-inch pipe line 2,500 feet long, under the same conditions the velocity may be increased to 2,500 feet per minute, but if the line is 7,000 feet long, it should not exceed 1,500 feet per minute.

In pipe lines smaller than the above, the velocity should be correspondingly diminished, but may be increased as the diameter of the line increases.

A friction loss of 10 per cent of the absolute pressure represents only a loss of three per cent in power, due to the fact that with decreased pressure the volume is increased nearly 11 per cent.

Volume and Density of Air at Various Temperatures

(AMERICAN BLOWER CO.)

Temperature	Volume of 1 lb. of Air at Atmospheric Pressure of 14.7 lbs.	Density or Weight of 1 cubic foot of Air at 14.7 lbs.	Temperature	Volume of 1 lb. of Air at Atmospheric Pressure of 14.7 lbs.	Density or Weight of 1 cubic foot of Air at 14.7 lbs.	Temperature	Volume of 1 lb. of Air at Atmospheric Pressure of 14.7 lbs.	Density or Weight of 1 cubic foot of Air at 14.7 lbs.
Degrees	Cubic Feet	Lbs.	Degrees	Cubic Feet	Lbs.	Degrees	Cubic Feet	Lbs.
0	11.583	.086331	220	17.111	.058442	575	26.031	.038415
32	12.387	.080728	240	17.612	.056774	600	26.659	.037510
40	12.586	.079439	260	18.116	.055200	650	27.915	.035822
50	12.840	.077884	280	18.621	.053710	700	29.171	.034280
62	13.141	.076097	300	19.121	.052297	750	30.428	.032865
70	13.342	.074950	320	19.624	.050959	800	31.684	.031561
80	13.593	.073565	340	20.126	.049686	850	32.941	.030358
90	13.845	.072230	360	20.630	.048476	900	34.197	.029242
100	14.096	.070942	380	21.131	.047323	950	35.454	.028206
120	14.592	.068500	400	21.634	.046223	1000	36.811	.027241
140	15.100	.066221	425	22.262	.044920	1500	49.375	.020295
160	15.603	.064088	450	22.890	.043686	2000	61.940	.016172
180	16.106	.062090	475	23.518	.042520	2500	74.565	.013441
200	16.606	.060210	500	24.146	.041414	3000	87.130	.011499
210	16.860	.059313	525	24.775	.040364	....	.....	......
212	16.910	.059135	550	25.403	.039365	....	.....	......

In the following formulas: V = velocity in feet per minute, A = area of pipe in inches, and Q = cubic feet of compressed air.

$$Q = \frac{a \times v}{144} \qquad A = \frac{Q \times 144}{V} \qquad V = \frac{Q \times 144}{a}$$

Q x number of atmospheres = cubic feet of free air.

Every increase of 20 degrees F. in the temperature of the atmosphere almost doubles its capacity for moisture; thus atmosphere at 32 degrees F. will sustain 2.1 grains of transparent vapor, at 52 degrees, 4.2 grains, and at 72 degrees, 8.6 grains.

Fans and Blowers

(KENT)

Two fans mounted on one shaft will be found more useful and convenient than one wide fan, as in such an arrangement twice the area of inlet opening is obtained as compared with a single fan. Such an arrangement may be adopted where occasionally half the full quantity of air is required, as one of them may be put out of gear, thus saving power.

The head or pressure is increased by increasing the number of revolutions of the fan.

Experiments have demonstrated that there is no practical difference between the efficiencies of blowers with curved blades and those with straight radial ones.

From 65% to 75% of the power expended on the blower is received back.

The greatest amount of power often used to run a fan is not due to the fan itself, but to the method of selecting, erecting and piping it.

Loss of Pressure Caused by Friction of Compressed Air in Pipes

(American Blower Co.)

Equivalent Volume in Cubic Feet of Free Air per Minute Passing Through Pipe	SIZE OF PIPE																		
	1	1¼	1½	2	2½	3	3½	4	5	6	7	8	9	10	12	14	16	18	20
	$P_1{}^2 - P_2{}^2$ = Difference in squares of initial and final absolute pressures, per 100 feet of pipe																		
50	150	49.2	20	4.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
75	335	98.5	46.2	10.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
100	600	197	79	18.8	6.15	...	...	...	...	...	...	...	...	...	...	...	...	...	...
150	1350	443	178	42.2	13.8	5.5	...	...	...	...	...	...	...	...	...	...	...	...	...
200	2400	788	316	75.0	24.6	9.9	2.0	2.4	...	...	...	...	...	...	...	...	...	...	...
250	3750	1230	494	117	38.5	15.4	7.1	3.6	...	...	...	...	...	...	...	...	...	...	...
300	5400	1770	711	168	55.4	22.2	10.3	5.3	...	...	...	...	...	...	...	...	...	...	...
400	9600	3150	1263	300	98.3	39.5	18.2	9.4	3.1	...	...	...	...	...	...	...	...	...	...
500	15000	4920	1978	470	154	62	28.5	14.6	4.8	...	...	...	...	...	...	...	...	...	...
600	21600	7100	2845	675	221	89	41	21.	6.9	...	...	...	...	...	...	...	...	...	...
800	...	12400	5070	1200	394	154	73	37.5	12.3	4.94	...	...	...	...	...	...	...	...	...
1000	...	19600	7900	1880	615	247	114	58.4	19.2	7.7	2.75	...	...	...	...	...	...	...	...
1500	...	44000	17800	4220	1380	555	255	132	43.2	17.4	8.0	...	...	...	...	...	...	...	...
2000	...	...	31600	7500	2460	990	455	234	77.	30.9	14.2	7.3	...	...	...	...	...	...	...
3000	...	...	71000	16800	5540	2220	1030	526	173.	69.5	32.1	16.5	9.15	...	...	...	...	...	...
4000	...	...	...	30000	9830	3950	1820	937	307.5	124	57	29.3	16.2	9.6	...	...	...	...	...
5000	...	...	...	47000	15500	6180	2850	1460	480.	193	89	45.7	25.4	15.	6.03	...	...	...	...
6000	...	...	...	68000	22300	8900	4100	2100	691.	278	128	66	36.5	21.6	8.7	...	...	...	...
8000	...	...	...	...	30600	15800	7300	3750	1230	494	228	117	65.5	38.5	15.4	7.1	...	...	...
10000	...	...	...	...	62000	24600	11400	5850	1920	771	356	183	101.8	60	24.1	11.2	5.7	...	...
15000	...	...	...	...	...	55000	25500	13180	4320	1740	801	412	228	135	54.1	25	12.9	7.1	...
20000	...	...	...	...	...	98000	45500	23500	7690	3090	1425	731	406	240	96.5	44.5	23	12.7	7.5
25000	...	...	...	...	...	...	71000	36500	12000	4950	2200	1130	635	375	150	70	36	19.8	11.7
30000	...	...	...	...	...	...	...	53000	17300	6950	3200	1650	920	540	217	100	51.5	28.5	16.8
35000	...	...	...	...	...	...	...	72000	23500	9500	4400	2250	1250	735	295	137	70	39	23
40000	...	...	...	...	...	...	...	93500	30700	12400	5700	2950	1630	960	386	178	91.5	50.5	30
50000	...	...	...	...	...	...	...	...	48000	19300	8900	4600	2540	1500	603	280	143	79.5	47
60000	...	...	...	...	...	...	...	...	71000	27800	12800	6600	3660	2160	870	414	206	114	67
80000	...	...	...	...	...	...	...	...	...	49500	22800	11800	6500	3950	1540	715	366	204	120
100000	...	...	...	...	...	...	...	...	...	77100	35600	18400	10200	6000	2420	1120	572	317	188

Weights of Galvanized Iron Pipe per Lineal Foot

Diameter of Pipes In Inches	GAUGE OF IRON—Numbers				
	18	20	22	24	26
3	2¼	1¾	1½	1¼	1
4	2¾	2¼	1¾	1½	1¼
5	3¼	2¾	2	1¾	1½
6	3¾	3	2¼	2	1¾
7	4½	3½	2¾	2¼	2
8	5¼	4	3	2¾	2¼
9	5¾	4½	3¼	3	2⅜
10	6¼	4¾	3½	3¼	2½
11	6¾	5¼	3¾	3½	2¾
12	7½	5¾	4¼	3¾	3
13	8	6¼	4½	4	3¼
14	8½	6¾	4¾	4¼	3½
15	9¼	7¼	5¼	4¾	3¾
16	9¾	7¾	5½	5	4
17	10¼	8	6	5¼	4¼
18	10¾	8½	6¼	5½	4½
19	11½	9	6¾	5¾	4¾
20	12	9½	7	6	5¼
21	12½	9¾	7½	6½	5½
22	13¼	10¼	7¾	6¾	5¾
23	14	11	8¼	7	6
24	14¾	11½	8¾	7½	6¼
26	15¾	12½	9¼	7¾	6½
28	16¾	13½	9¾	8½	7
30	18	14	10½	9	7½
32	19¼	15	11¼	9¾	8
34	20¼	15¾	12	10¼	8½
36	21½	16¾	12½	10¾	9
38	22¼	18	13½	11½	9½
40	24	18¾	14	12	10
42	25	19½	14¾	12½	10½
44	26¼	20½	15½	13	11
46	27½	21¼	16	13¾	11½
48	28½	22¼	16¾	14¼	12
50	29¾	23	17½	15	12½
52	31¼	24¼	18¼	....	....
54	32½	25	18¾	....	....
56	33¾	26	19	....	....
58	35	26¾	20¼	....	....
60	36¼	27½	20¾	....	....
63	38¼	29	21¾	....	....
66	40	30¼	22¾	....	....
69	41¾	32¼	23¾	....	....
72	43½	33¼	25	....	....

Forced Draft Capacity Table for Blowers

Temp. Air 62° F.
Barometer 29.92.
Pressure 1½ ounces.

18 lb. Air per one lb. Coal.
234 cu. ft. per one lb. Coal.
5 lb. Coal per H. P. hour.

34.5 lb. Water per H. P.
Evaporation 6.9 lb. Water one lb. Coal.

Size of Blower	Diameter Wheel Inches	Width at Periphery	Diameter of Inlet	Diameter of Outlet	Speed R.P.M. for 1½" Pressure	Capacity Blower, cu. ft. per minute Temp. 62° F.	Lbs. Coal per Hour, 234 cu. ft. Air per Lb. Coal	H. P. Boiler Capacity 5 Lb. Coal per H. P. Hour	Evaporation per Hour 34.5 Lbs. Water Per H. P.	Brake H. P. to Drive Blower at Speed
1	8½	2	4⅜	4⅝	3300	348	90	18	620	.35
2	10¼	2¾	5⅛	5⅝	2650	512	131	26	896	.52
3	12	3¼	6⅛	6⅝	2320	711	182	36	1240	.73
4	15½	4⅜	8	8½	1800	1210	310	62	2140	1.24
5	19	5½	10	10½	1470	1830	468	93	3210	1.87
6	22½	6½	12	12½	1240	2600	666	133	4590	2.66
7	26	7½	14	14½	1075	3420	875	175	6030	3.50
8	29½	8½	15¾	16¼	950	4130	1055	211	7280	4.54
9	33	9½	17¾	18¼	845	5580	1425	285	9820	5.72

Flow of Air Through Orifices

(American Blower Co.)

Flow is expressed in cubic feet per minute, and is assumed to take place from a receiver or other vessel in which air is contained under pressure into the atmosphere at sea level. Temperature of air in receiver is assumed at 60° Fahr. This table is only correct for orifices with narrow edges; flow through even a short length of pipe would be less than that given below.

Gauge Press. in Receiver (Pounds)	Diameter of Orifice—Inches																				
	1/64	1/32	3/64	1/16	3/32	1/8	3/16	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 3/4	2	2 1/2
1	.027	.107	.242	.430	.97	1.72	3.86	6.85	15.4	27	43	62	84	110	139	172	207	247	336	440	688
2	.038	.153	.342	.607	1.36	2.43	5.42	9.74	21.9	39	61	88	119	156	196	242	291	350	473	625	967
3	.046	.188	.471	.750	1.68	2.98	6.71	11.9	26.9	48	75	108	146	191	242	298	361	430	585	764	1190
5	.059	.242	.545	.965	2.18	3.86	8.71	15.4	34.6	67	96	133	189	247	310	384	464	550	752	985	1540
10	.084	.342	.77	1.36	3.06	5.45	12.3	21.8	49.	87	136	196	267	350	440	543	660	780	1068	1395	
15	.103	.418	.94	1.67	3.75	6.65	15.0	26.7	60.	107	167	240	326	427	538	665	803	960	1304	1700	
20	.119	.485	1.07	1.93	4.25	7.7	17.1	30.8	69.	123	193	277	378	494	620	770	929	1102	1505	1967	
25	.133	.54	1.21	2.16	4.75	8.6	19.4	34.5	77.	138	216	310	422	550	692	860	1040	1240	1680		
30	.156	.632	1.40	2.52	5.6	10.	22.5	40.0	90.	161	252	362	493	645	812	1000	1200	1435	1960		
35	.173	.71	1.56	2.80	6.2	11.2	25.0	44.7	100.	179	280	400	550	715	900	1120	1350	1600			
40	.19	.77	1.71	3.07	6.8	12.3	27.5	49.1	110.	196	307	442	601	785	987	1230	1480	1770			
45	.208	.843	1.9	3.36	7.6	13.4	30.3	53.8	121.	215	336	482	658	860	1082	1345	1630	1930			
50	.225	.914	2.05	3.64	8.2	14.5	32.8	58.2	130.	232	364	522	710	930	1170	1455	1760				
60	.26	1.05	2.35	4.2	9.4	16.8	37.5	67.	151.	268	420	604	622	1070	1350	1680					
70	.295	1.19	2.68	4.76	10.7	19.0	43.0	76.	171.	304	476	685	950	1215	1530	1900					
80	.33	1.33	2.97	5.32	11.9	21.2	47.5	85.	191.	340	532	765	1004	1360	1710						
90	.364	1.47	3.28	5.87	13.1	23.5	52.5	94.	211.	376	587	843	1145	1500	1890						
100	.40	1.61	3.66	6.45	14.5	25.8	58.3	103.	231.	412	645	925	1260	1648							
110	.43	1.76	3.95	7.00	15.7	28.0	63.	112.	252.	446	700	960	1370	1810							
120	.47	1.90	4.27	7.58	17.0	30.2	68.	121.	272.	484	758	1090	1480	1960							
130	.50	2.04	4.57	8.13	18.2	32.4	73.	130.	291.	518	813	1170	1590								
140	.54	2.17	4.87	8.68	19.5	34.5	78.	138.	311.	552	868	1242	1700								
150	.57	2.33	5.20	9.20	20.7	36.7	83.	147.	330.	588	920	1322	1804								
175	.66	2.65	5.94	10.6	23.8	42.1	95.	169.	378.	675	1060	1520									
200	.76	3.07	6.90	12.2	27.5	48.7	110.	195.	440.	782	1220	1760									

Volume of Air Transmitted in Cubic Feet Per Minute in Pipes of Various Diameters

(KENT)

Velocity of Flow	Actual Diameter of Pipe in Inches											
Feet per Second	1	2	3	4	5	6	8	10	12	16	20	24
1	.327	1.31	2.95	5.24	8.18	11.78	20.94	32.73	47.12	83.77	130.9	188.5
2	.655	2.62	5.89	10.47	16.36	23.56	41.89	65.45	94.25	167.5	261.8	377.
3	.982	3.93	8.84	15.7	24.5	35.3	62.8	98.2	141.4	251.3	392.7	565.5
4	1.31	5.24	11.78	20.9	32.7	47.1	83.8	131.	188.	335.	523.	754.
5	1.64	6.54	14.7	26.2	41.	59.	104.	163.	235.	419.	654.	942.
6	1.96	7.85	17.7	31.4	49.1	70.7	125.	196.	283.	502.	785.	1131.
7	2.29	9.16	20.6	36.6	57.2	82.4	146.	229.	330.	586.	916.	1319.
8	2.62	10.5	23.5	41.9	65.4	94.	167.	262.	377.	670.	1047.	1508.
9	2.95	11.78	26.5	47.	73.	106.	188.	294.	424.	754.	1178.	1696.
10	3.27	13.1	29.4	52.	82.	118.	209.	327.	471.	838.	1309.	1885.
12	3.93	15.7	35.3	63.	98.	141.	251.	393.	565.	1005.	1571.	2262.
15	4.91	19.6	44.2	78.	122.	177.	314.	491.	707.	1256.	1963.	2827.
18	5.89	23.5	53.	94.	147.	212.	377.	589.	848.	1508.	2356.	3393.
20	6.54	26.2	59.	105.	164.	235.	419.	654.	942.	1675.	2618.	3770.
24	7.85	31.4	71.	125.	196.	283.	502.	785.	1131.	2010.	3141.	4524
25	8.18	32.7	73.	131.	204.	294.	523.	817.	1178.	2094.	3272.	4712.
28	9.16	36.6	82.	146.	229.	330.	586.	916.	1319.	2346.	3665.	5278.
30	9.8	39.3	88.	157.	245.	353.	628.	982.	1414.	2513.	3927.	5655.

Quantity of Air of a Given Density Delivered by a Fan

(Kent)

Total area of nozzles in square feet multiplied by velocity in feet per minute corresponding to density (see table) equals air delivered in cubic feet per minute.

Density Ounces Per Square Inch	Velocity Feet Per Min.	Density Ounces Per Square Inch	Velocity Feet Per Min.	Density Ounces Per Square Inch	Velocity Feet Per Min.
1	5000	5	11000	9	15000
2	7000	6	12250	10	15800
3	8600	7	13200	11	16500
4	10000	8	14150	12	17300

Comparative Efficiency of Fans and Positive Blowers

(H. M. Howe, Trans. A. I. M. E. x 482). Experiments with fans and positive (Baker) blowers working at moderately low pressures, under 20 ounces, show that they work more efficiently at a given pressure when delivering large volumes (i. e. when working nearly up to their maximum capacity) than when delivering comparatively small volumes. Therefore, when great variations in the quantity and pressure of blast required are liable to arise, the highest efficiency would be obtained by having a number of blowers, always driving them up to their full capacity, and regulating the amount of blast by altering the number of blowers at work, instead of having one or two very large blowers and regulating the amount of blast by the speed of the blowers.

For a given speed of a fan, any diminution in the size of the blast-orifice decreases the consumption of power and at the same time raises the pressure of the blast; but it increases the consumption of power per unit of orifice for a given pressure of blast. When the orifice has been reduced to the normal size for any given fan, further diminishing it causes but slight elevation of the blast pressure; and, when the orifice becomes comparatively small, further diminishing it causes no sensible elevation of the blast pressure, which remains practically constant, even when the orifice is entirely closed.

Many of the failures of fans have been due to too low speed, to too small pulleys, to improper fastening of belts, or to the belts being too nearly vertical; in brief, to bad mechanical arrangement, rather than to inherent defects in the principles of the machine.

If several fans are used, it is probably essential to high efficiency to provide a separate blast-pipe for each (at least if the fans are of different size or speed) while any number of positive blowers may deliver into the same pipe without lowering their efficiency.

Formula for Calculating Friction Losses

P_1 = Absolute initial air pressure (lbs.)
P_2 = Absolute terminal air pressure (lbs.)
V = Free air equivalent in cu. ft. per min. of volume passing through pipe.
L = Length of pipe (feet)
A = Diameter of pipe (inches)

Formula

$$P_1^2 - P_2^2 = \frac{.0006v^2L}{A^5}$$

Loss of Air Pressure in Ounces per Square Inch for Varying Velocities and Varying Diameters of Pipes

(American Blower Co.)

Velocity of Air Feet per Minute	Diameter of Pipe in Inches							
	1	2	3	4	5	6	7	8
	Loss of Pressure in Ounces							
600	.400	.200	.133	.100	.080	.067	.057	.050
1,200	1.600	.800	.533	.400	.320	.267	.229	.200
1,800	3.600	1.800	1.200	.900	.720	.600	.514	.450
2,400	6.400	3.200	2.133	1.600	1.280	1.067	.914	.800
3,000	10.000	5.000	3.333	2.500	2.000	1.667	1.429	1.250
3,600	14.400	7.200	4.800	3.600	2.880	2.400	2.057	1.800
4,200	......	9.800	6.553	4.900	3.920	3.267	2.800	2.450
4,800	......	12.800	8.533	6.400	5.120	4.267	3.657	3.200
6,000	......	20.000	13.333	10.000	8.000	6.667	5.714	5.000

Velocity of Air Feet per Minute	Diameter of Pipe in Inches							
	9	10	11	12	14	16	18	20
	Loss of Pressure in Ounces							
600	.044	.040	.036	.033	.029	.026	.022	.020
1,200	.178	.160	.145	.133	.114	.100	.089	.080
1,800	.400	.360	.327	.300	.257	.225	.200	.180
2,400	.711	.640	.582	.533	.457	.400	.356	.320
3,000	1.111	1.000	.909	.833	....	....	....	....
3,600	1.600	1.440	1.309	1.200	1.029	.900	.800	.720
4,200	2.178	1.960	1.782	1.633	1.400	1.225	1.089	.980
4,800	2.844	2.560	2.327	2.133	1.829	1.600	1.422	1.280
6,000	4.444	4.000	3.636	3.333	2.857	2.500	2.222	2.000

Velocity of Air Feet per Minute	Diameter of Pipe in Inches							
	22	24	28	32	36	40	44	48
	Loss of Pressure in Ounces							
600	.018	.017	.014	.012	.011	.010	.009	.008
1,200	.073	.067	.057	.050	.044	.040	.036	.033
1,800	.164	.156	.129	.112	.100	.090	.082	.075
2,400	.291	.267	.239	.200	.178	.160	.145	.133
3,600	.655	.600	.514	.450	.400	.360	.327	.300
4,200	.891	.817	.700	.612	.544	.490	.445	.408
4,800	1.164	1.067	.914	.800	.711	.640	.582	.533
6,000	1.818	1.667	1.429	1.250	1.111	1.000	.909	.833

Displacement in Cubic Feet per Minute of a Piston Working in a Single Cylinder at Varying Piston Speeds

Diameter of Piston Inches	Piston Speeds in Feet per Minute																	
	100	150	200	225	250	275	300	325	350	375	400	425	450	475	500	550	600	700
3	4.9	7.4	9.8	11.1	12.3	13.5	14.7	16.	17.2	18.5	19.6	21.	22.2	23.4	24.6	27.	29.4	34.4
4	8.7	13.1	17.4	19.7	21.8	24.	26.2	28.5	30.7	32.9	34.8	37.2	39.4	41.5	43.6	48.	52.4	61.4
5	13.6	20.5	27.2	30.8	34.2	37.5	41.	44.5	48.	51.4	54.4	58.	61.6	65.	68.4	75.	82.	96.
6	19.6	29.5	39.2	44.0	49.	54.	59.	64.	69.	74.	78.4	84.	88.8	93.	98.	108.	118.	138.
7	26.7	40.	53.4	60.5	67.	74.	80.	87.	94.	100.6	106.8	114.	121.	127.	131.	148.	160.	188.
8	35.	52.5	70.	79.	87.5	96.	105.	114.	123.	132.	140.	149.	158.	165.	175.	192.	210.	246.
9	44.	66.5	88.	100.	110.	122.	133.	144.	155.	166.	176.	188.	200.	210.	220.	244.	266.	310.
10	54.5	82.	109.	123.	136.	150.	164.	178.	192.	206.	218.	233.	246.	260.	272.	300.	328.	384.
11	66.	99.	132.	149.	165.	182.	198.	215.	232.	250.	264.	282.	298.	315.	330.	364.	396.	464.
12	78.	118.	156.	177.	196.	216.	236.	256.	276.	296.	312.	335.	354.	374.	392.	432.	472.	552.
13	92.	138.	184.	208.	230.	255.	276.	300.	325.	345.	368.	392.	416.	440.	460.	510.	552.	650.
14	106.	160.	212.	240.	266.	295.	320.	348.	375.	400.	424.	455.	480.	510.	532.	590.	640.	750.
15	122.	184.	244.	276.	305.	337.	368.	400.	432.	460.	488.	521.	552.	580.	610.	674.	736.	864.
16	139.	210.	278.	315.	350.	385.	420.	455.	490.	525.	556.	595.	630.	660.	700.	790.	840.	980.
17	157.	236.	314.	355.	395.	435.	472.	512.	550.	590.	628.	672.	710.	750.	790.	870.	944.	1100.
18	176.	265.	352.	400.	440.	485.	530.	575.	620.	660.	704.	755.	800.	840.	880.	970.	1060.	1240.
19	196.	295.	392.	445.	490.	540.	590.	640.	690.	740.	784.	840.	890.	930.	980.	1080.	1180.	1380.
20	218.	328.	436.	490.	545.	600.	656.	710.	765.	820.	872.	930.	980.	1040.	1090.	1200.	1312.	1530.
22	265.	395.	530.	595.	660.	725.	790.	860.	930.	990.	1060.	1120.	1190.	1260.	1320.	1450.	1580.	1860.
24	314.	470.	628.	710.	790.	865.	940.	1020.	1100.	1180.	1256.	1340.	1420.	1500.	1580.	1730.	1880.	2200.
26	369.	550.	738.	830.	920.	1020.	1100.	1200.	1300.	1390.	1476.	1570.	1660.	1750.	1840.	2040.	2200.	2600.
28	427.	640.	854.	960.	1070.	1180.	1280.	1390.	1500.	1600.	1780.	1820.	1920.	2030.	2140.	2360.	2560.	3000.
30	490.	740.	980.	1110.	1230.	1350.	1480.	1600.	1720.	1840.	1960.	2100.	2220.	2310.	2460.	2700.	2960.	3440.
32	560.	835.	1120.	1260.	1400.	1540.	1670.	1820.	1960.	2100.	2240.	2380.	2520.	2660.	2800.	3080.	3340.	3920.
34	630.	945.	1260.	1420.	1570.	1740.	1890.	2050.	2220.	2360.	2520.	2690.	2840.	3000.	3140.	3480.	3780.	4440.
36	710.	1060.	1420.	1600.	1770.	1950.	2120.	2300.	2500.	2650.	2840.	3000.	3200.	3360.	3540.	3900.	4240.	5000.
38	780.	1180.	1560.	1780.	1960.	2170.	2360.	2560.	2750.	2950.	3120.	3350.	3560	3750.	3920.	4340.	4720.	5500.
40	870.	1310.	1740.	1970.	2180.	2400.	2620.	2850.	3060.	3280.	3480.	3720.	3940	4150.	4360.	4800.	5240.	6120.

As an example of the use of the above table, let it be required to find the displacement of a 12 × 12 duplex double-acting compressor running at 150 revolutions per minute. The travel per revolution of one piston being two feet, the total travel of one piston per minute will be $150 \times 2 = 300$ feet. By the table the displacement of a 12-inch piston at 300 feet is 236 cubic feet per minute; the total displacement, therefore, for the two pistons constituting the duplex compressor will be twice 236, or 472 cubic feet per minute.

Hydraulics

Useful Notes for Hydraulic Calculations

1 Cubic foot of water	62.3791	lbs.
1 Cubic inch of water	.03612	"
1 Gallon of water	8.338	"
1 Gallon of water	231.	cubic inches
1 Cubic foot of water	7.476	gallons
1 Pound of water	27.7	cubic inches

The above data is calculated for distilled water at 40° F.

Pressure Determinations

P = Pressure in pounds per square inch.
H = Head of water in feet.
$P = H \times .4335.$
$H = P \times 2.307.$
Pressure per square foot $= H \times 62.425.$

Approximately, every foot of elevation is equal to ½ pound pressure per square inch; this allows for ordinary friction.

Speed of Water should not exceed 100 feet per minute with 700 pounds pressure.

To Find the Capacity of a Cylinder in Gallons: Multiplying the area in inches by the length of stroke in inches will give the total number of cubic inches; divide this amount by 231 (which is the cubical contents of a gallon in inches) and the product is the capacity in gallons.

To Find Quantity of Water elevated in one minute running at 100 feet of piston speed per minute. Square the diameter of water cylinder in inches and multiply by four. Capacity of a five-inch cylinder is desired; the square of the diameter (five inches) is 25, which, multiplied by four gives 100, giving gallons discharged per minute (approximately).

To Find the Diameter of a Pump Cylinder to Move a given quantity of water per minute (100 feet of piston travel being the speed) divide the number of gallons by four, then extract the square foot and the result will be the diameter in inches.

To Find the Pressure in Pounds per Square Inch, due to forcing a given quantity of water through a certain size of pipe (table of friction of water in pipes, page 203). Add the amount of this friction to the pressure due to the height of which water is to be forced; the result is total water pressure.

The Area of Steam Piston multiplied by the steam pressure gives the total amount of pressure exerted. The area of the water piston multiplied by the pressure of water per square inch gives the resistance. A margin must be made between the power and resistance to move the pistons at the required speed; usually estimated at from 25 to 50 per cent.

Friction of Water in Pipes

Friction Loss in Pounds Pressure Per Square Inch for Each 100 Feet of Length in Different Size Clean Iron Pipes Discharging Given Quantities of Water Per Minute

Gallons Per Minute	Sizes of Pipes—Inside Diameter																	
	¾-in.	1-in.	1¼-in.	1½-in.	2-in.	2½-in.	3-in.	4-in.	6-in.	8-in.	10-in.	12-in.	14-in.	16-in.	18-in.	20-in.	24-in.	30-in.
5	3.3	0.84	0.31	0.12														
10	13.0	3.16	1.05	0.47	0.12													
15	28.7	6.98	2.38	0.97														
20	50.4	12.3	4.07	1.66	0.42													
25	78.0	19.0	6.40	2.62		0.21	0.10											
30		27.5	9.15	3.75	0.91													
35		37.0	12.4	5.05														
40		48.0	16.1	6.52	1.60													
45			20.2	8.15														
50			24.9	10.0	2.44	0.81	0.35	0.09										
75			56.1	22.4	5.32	1.80	0.74											
100				39.0	9.46	3.20	1.31	0.33	0.05									
125					14.9	4.89	1.99											
150					21.2	7.0	2.85	0.69	0.10									
175					28.1	9.46	3.85											
200					37.5	12.47	5.02	1.22	0.17									
250						19.66	7.76	1.89	0.26	0.07	0.03	0.01						
300						28.06	11.2	2.66	0.37	0.09	0.04							
350							15.2	3.65	0.50	0.12	0.05	0.02						
400							19.5	4.73	0.65	0.16	0.06							
450							25.0	6.01	0.81	0.20	0.07	0.03						
500							30.8	7.43	0.96	0.25	0.09	0.04	0.017	0.009	0.005			
750									2.21	0.53	0.18	0.08						
1000									3.88	0.94	0.32	0.13	0.062	0.036	0.020	0.012	0.005	0.002
1250										1.46	0.49	0.20						
1500										2.09	0.70	0.29	0.135	0.071	0.040			
1750											0.95	0.38						
2000											1.23	0.49	0.234	0.123	0.071	0.042	0.020	0.006
2250												0.63						
2500												0.77	0.362	0.188	0.107			
3000												1.11	0.515	0.267	0.150	0.091	0.047	0.012
3500													0.697	0.365	0.204			
4000													0.910	0.492	0.263	0.158	0.067	0.022
4500														0.593	0.333			
5000														0.730	0.408	0.244	0.102	0.035
6000															0.585	0.348	0.146	0.048
7000																0.472	0.196	0.065
8000																0.612	0.255	0.083
9000																	0.323	0.105
10000																	0.398	0.131

To Find the Velocity in feet per minute necessary to discharge a given column of water in a given time, multiply the number of cubic feet of water by 144, and divide the product by the area of pipe in inches.

To Find the Area of a Required Pipe, the volume and velocity of water being given, multiply the number of cubic feet of water by 144, and divide the product by the velocity in feet per minute. The area being found, it is easy to get the diameter of pipe necessary.

The Mean Pressure of the Atmosphere is estimated at 14.7 pounds per square inch. With a perfect vacuum at sea level, it will therefore sustain a column of mercury 29.9 inches, or a column of water 33.9 feet.

The friction of water in pipes increases with the square of its velocity. The capacity of pipe increases with the square of their diameter, thus doubling the diameter increases the capacity four times.

To Find the Horse Power required to elevate water to a given height; multiply the total weight of the water in pounds by the height in feet, and divide the product by 33,000. An allowance should be made of 25 per cent for water friction; also about 25 per cent for loss in steam pipe and cylinder.

Capacity of Pipes: A pipe one yard long holds as many pounds of water as the square of its diameter, in inches. Thus, six-inch pipe holds 36 pounds of water in each yard of length.

One Miner's Inch of Water equals 12 United States Gallons per minute.

A common water pail filled, contains 19 pounds of water and equals 2.272 United States Gallons.

Steam

A CUBIC inch of water under ordinary atmospheric pressure is converted into one cubic foot of steam (approximately).

The specific gravity of steam (at atmospheric pressure) is .411 that of air at 34° F., and .0006 that of water at same temperature.

Twenty-seven and two hundred and twenty-two thousandths (27.222) cubic feet of steam weighs one pound; 13.817 cubic feet of air weighs one pound.

Saturated Steam: Steam at a given temperature is said to be saturated when it is of maximum density for that temperature. Steam in contact with water is saturated steam.

Wet or Supersaturated Steam: Steam which has water (in the form of small drops) suspended in it is called wet or supersaturated steam. If wet steam be heated until all the water suspended in it is evaporated, it is said to be dried.

Superheated Steam: If dry saturated steam be heated when not in contact with water, its temperature is raised and its density diminished or the pressure is raised. The steam is then said to be superheated.

Dryness Fraction of Steam: Let W = Weight of a given quantity of wet steam, w = Weight of water suspended in this steam, then dryness fraction $= \frac{W - w}{W}$

Under ordinary conditions and good stoking, the dryness fraction is about 95%.

A Unit of Evaporation is the quantity of heat necessary to evaporate one pound of water at 212° into steam at the same temperature, and is equal to 965.8 B. T. U.

One horse power = 42.416 heat units per minute or 2,545 per hour, equivalent to 1,980,000 foot-pounds of work done.

Heat Units

(FOSTER)

One pound of water evaporated from and at 212° F.	0.283	K. W. hour.
	0.39	H. P. hour.
	966.	B. T. U.
	751,300.	Foot-pounds.
	.0664	lbs. Carbon oxidized at 100% Eff.
1 H. P. Hour.	2,545.	B. T. U.
	0.746	K. W. hours.
	1,980,000.	Foot-pounds.
	0.175	lbs. Carbon oxidized at 100% Eff.
K. W. Hour.	.235	lbs. Carbon oxidized at 100% Eff.
	22.8	lbs. water raised from 62° to 212° F.
	3.53	lbs. water evaporated at 212° F.
	3,412.	B. T. U.
	2,654,200.	Foot-pounds.
One pound carbon oxidized at 100% efficiency.	14,500.	B. T. U.
	1.11	lbs. Anth. Coal oxidized at 100%.
	2.5	lbs. Dry Wood oxidized at 100%.
	21.	Cubic feet Illum. Gas at 100%.
	4.26	K. W. hours at 100% Eff.
	5.71	H. P. hours at 100% Eff.
	11,315,000.	Foot-pounds at 100% Eff.
	15.	lbs. water evaporated at 212° F.

British Thermal Unit: The quantitive measure of heat is the British Thermal Unit. It is ordinarily written B. T. U. and is the quantity of heat required to raise the temperature of a pound of pure water one degree at its point of maximum density, viz.: 39.1 degrees F. In the metric system the unit is the calorie or the heat necessary to raise the temperature of a kilogramme of water one degree Centigrade at the point of maximum density.

Measure of Power

The unit of work is "the foot-pound," which is a pressure of one pound exerted through a space of one foot.

The rate of work is "the horse power" or 33,000 foot-pounds per minute =1,980,000 foot-pounds per hour.

The unit of heat is the amount of heat required to raise one pound of water one degree from 39 degrees to 40 degrees.

Properties of Saturated Steam

Pressure	Absolute Pressure	Temperature Fahrenheit	Total Heat Above 32 Degrees: Heat Units in the Water	Total Heat Above 32 Degrees: Heat Units in the Steam	Latent Heat	Relative Volume 39°=1	Volume C. F. in 1 lb. Steam	Weight 1 Cubic Foot Steam Lbs.
0.	14.7	212.	180.9	1146.6	965.7	1646.	26.36	.03794
1.3	16.	216.3	185.3	1147.9	962.7	1519.	24.33	.04110
2.3	17.	219.4	188.4	1148.9	960.5	1434.	22.98	.04352
3.3	18.	222.4	191.4	1149.8	958.3	1359.	21.78	.04592
4.3	19.	225.2	194.3	1150.6	956.3	1292.	20.70	.04831
5.3	20.	227.9	197.0	1151.5	954.4	1231.	19.72	.05070
10.3	25.	240.0	209.3	1155.1	945.8	998.4	15.99	.06253
15.3	30.	250.2	219.7	1158.3	938.9	841.3	13.48	.07420
20.3	35.	259.2	228.8	1161.0	932.2	727.9	11.66	.08576
25.3	40.	267.1	236.9	1163.4	926.5	642.0	10.28	.09721
30.3	45.	274.3	244.3	1165.6	921.3	574.7	9.21	.1086
40.3	55.	286.9	257.2	1169.4	912.3	475.9	7.63	.1311
50.3	65.	297.8	268.3	1172.8	904.5	406.6	6.53	.1533
60.3	75.	307.4	278.2	1175.7	897.5	355.5	5.71	.1753
70.3	85.	316.0	287.0	1178.3	891.3	315.9	5.07	.1971
80.3	95.	323.9	295.1	1180.7	885.6	284.5	4.57	.2188
90.3	105.	331.1	302.6	1182.9	880.3	258.9	4.16	.2403
100.3	115.	337.8	309.5	1185.0	875.5	237.6	3.82	.2617
125.3	140.	352.8	325.0	1189.5	864.6	197.3	3.18	.3147
150.3	165.	365.7	338.4	1193.5	855.1	169.0	2.72	.3671
200.3	215.	387.7	361.3	1200.2	838.9	131.5	2.12	.4707

Horse Power: The term horse power was first established by James Watt, who ascertained that a strong London draught horse was capable of doing work for a short interval of time equivalent to lifting 33,000 pounds one foot high in one minute.

This value was used by Watt in expressing the power of his engines and has since been universally adopted in mechanics. The expression foot-pounds is used to denote the unit of work, and is the force required to lift a weight of one pound through a space of one foot.

Horse power is the measure of the rate at which work is performed and is equal to 33,000 pounds lifted one foot in one minute, or one pound lifted 33,000 feet in one minute, or one pound lifted 550 feet in one second, therefore one horse power equals 550 foot-pounds per second.

Horse Power of an Engine

A = Area of the piston in square inches.
P = Mean effective pressure of the steam on the piston per square inch.
V = Velocity of piston per minute.

$$\text{Then H. P.} = \frac{A \times P \times V}{33{,}000}$$

The mean pressure in the cylinder when cutting off at

¼	stroke	=	boiler	pressure	multiplied	by .597.
⅓	"	=	"	"	"	" .670.
⅜	"	=	"	"	"	" .743.
½	"	=	"	"	"	" .847.
⅝	"	=	"	"	"	" .919.
⅔	"	=	"	"	"	" .937.
¾	"	=	"	"	"	" .966.
⅞	"	=	"	"	"	" .992.

To find the diameter of a cylinder of an engine of a required nominal horse power:

$$\frac{5500}{v} \text{ multiplied by H. P.} = \text{A.}$$

To find the weight of the rim of the fly wheel for an engine:

$$\frac{\text{Nominal H. P. multiplied by 2000.}}{\text{The square of the velocity of the circumference in feet per second}} = \text{weight in cwt.}$$

Compound engines will develop a horse power on 15 pounds of water.

Single condensing engine will develop a horse power on 18 to 22 pounds of water.

Automatic non-condensing engine will develop a horse power on 28 to 32 pounds of water.

Slide-valve throttle-governing engine will develop a horse power on one cubic foot, or 62½ pounds of water.

Steam engines, in economy, vary from 14 to 60 pounds of feed water, and from 1½ to 7 pounds of coal per hour per indicated horse power.

Cost of Coal for Steam Power

Horse Power	COAL CONSUMPTION at 4 lbs. per H. P. per hour; 10 hours a day; 300 days in a year					$1.50		$2.00		$3.00		$4.00	
	Lbs.	Long Tons		Short Tons		Per Short Ton Cost in Dollars		Per Short Ton Cost in Dollars		Per Short Ton Cost in Dollars		Per Short Ton Cost in Dollars	
	Per Day	Per Day	Per Year	Per Day	Per Year	Per Day	Per Year	Per Day	Per Year	Per Day	Per Year	Per Day	Per Year
1	40	.0179	5.357	.02	6	.03	9	.04	12	.06	18	.08	24
10	400	.1786	53.57	.20	60	.30	90	.40	120	.60	180	.80	240
25	1,000	.4464	133.92	.50	150	.75	225	1.00	300	1.50	450	2.00	600
50	2,000	.8928	267.85	1.00	300	1.50	450	2.00	600	3.00	900	4.00	1,200
75	3,000	1.3393	401.78	1.50	450	2.25	675	3.00	900	4.50	1,350	6.00	1,800
100	4,000	1.7857	535.71	2.00	600	3.00	900	4.00	1,200	6.00	1,800	8.00	2,400
150	6,000	2.6785	803.56	3.00	900	4.50	1,350	6.00	1,800	9.00	2,700	12.00	3,600
200	8,000	3.5714	1,071.42	4.00	1,200	6.00	1,800	8.00	2,400	12.00	3,600	16.00	4,800
250	10,000	4.4642	1,339.27	5.00	1,500	7.50	2,250	10.00	3,000	15.00	4,500	20.00	6,000
300	12,000	5.3571	1,607.13	6.00	1,800	9.00	2,700	12.00	3,600	18.00	5,400	24.00	7,200
350	14,000	6.2500	1,874.98	7.00	2,100	10.50	3,150	14.00	4,200	21.00	6,200	28.00	8,400
400	16,000	7.1428	2,142.84	8.00	2,400	12.00	3,600	16.00	4,800	24.00	7,200	32.00	9,600
450	18,000	8.0356	2,410.69	9.00	2,700	13.50	4,050	18.00	5,400	27.00	8,100	36.00	10,800
500	20,000	8.9285	2,678.55	10.00	3,000	15.00	4,500	20.00	6,000	30.00	9,000	40.00	12,000

Condensing engines require from 20 to 30 gallons of water, at an average low temperature, to condense the steam represented by every gallon of water evaporated in the boilers supplying the engines, approximately for most engines, we say, from 1 to 1½ gallons condensing water per minute, per indicated horse power.

The standard rating for surface condensers is to allow one square foot of tube surface for every 10 pounds of steam condensed, or two square feet for every horse power in compound engines.

In order to maintain a good working vacuum, the condensed water from the air pump should not exceed 120 degrees to 130 degrees F. in temperature, nor the discharged circulating water 110 degrees to 120 degrees F.

Ordinary steam engines with a superheat of 125 degrees F. on a pressure of 100 pounds, will effect a saving of from 10 to 25%.

Data on Steam Boilers

A standard boiler horse has been adopted by the American Society of Mechanical Engineers as the evaporation of 30 pounds of water per hour from the temperatures of feed water 100° F. into steam of 70 pounds pressure.

Boilers require for each nominal horse power about one cubic foot of feed water per hour.

The best designed boilers, well set, with good draft and skillful firing, will evaporate from 7 to 10 pounds of water per pound of first-class coal.

On one square foot of grate can be burned on an average from 10 to 12 pounds of hard coal, or 18 to 20 pounds of soft coal per hour with natural draft. With forced draft nearly double these amounts can be burned. The average result is from 25 to 60% below this.

In calculating horse power of horizontal, tubular, or flue boilers, consider 15 square feet of heating surface equivalent to one nominal horse power.

Firing: Coal of a depth up to 12 inches is more effective than at less depth. Admission of air above the grate increases evaporative effect, but diminishes the rapidity of it. Air admitted at bridge-wall effects a better result than when admitted at door, and when in small volumes, and in streams or currents, it arrests or prevents smoke. It may be admitted by an area of four square inches per square foot of grate. Combustion is the most complete with firings at intervals of from 15 to 20 minutes.

The rate of combustion in a furnace is computed by the pounds of fuel consumed per square foot of grate per hour.

Consumption of fuel averages 7½ pounds of coal or 15 pounds dry pine wood for every cubic foot of water evaporated.

The dimensions or size of coal must be reduced and the depth of the fire increased directly, as the intensity of the draught is increased.

Fuels

FUELS may be solid, liquid or gaseous. Such representatives of each class as are used in the manufacture of glass will be considered.

Coal

Coal is the fossilized remains of prehistoric vegetable growth. In its stages from vegetable to almost pure carbon in the form of graphite, it was successively changed in the forms given in the following table which gives the approximate chemical changes.

(STERLING)

Substance	Carbon	Hydrogen	Oxygen
Wood Fibre	52.65	5.25	42.10
Peat	59.57	5.96	34.47
Lignite	66.04	5.27	28.69
Earthy brown coal	73.18	5.58	21.14
Bituminous coal	75.06	5.84	19.10
Semi-Bituminous coal	89.29	5.05	6.66
Anthracite coal	91.58	3.96	4.46

The percentage of ash and moisture vary greatly. The ash ranges from 3 to 30%; and the moisture from 0.75 to 25% of the total weight of the coal, depending upon the locality where mined and the grade.

The uncombined carbon in coal is known as *fixed carbon.*

There is also some carbon combined with hydrogen, and this, together with other gaseous substances driven off by the application of heat, constitute the volatile portion of the fuel. The fixed carbon and the volatile matter constitute the combustible, the other important ingredients entering with the composition of coal being *moisture*, and the refractory earths which form the *ash*. A large percentage of ash is undesirable, because it not only reduces the calorific value of the fuel, but in the furnace clogs up the air passages and prevents the rapid combustion necessary to high efficiency. If the coal also contains an excessive quantity of sulphur, trouble will be experienced because sulphur unites with the ash to form a fusable slag or clinker which chokes up the grate bars and forms a solid mass, having imbedded in it large quantities of unconsumed carbon. Moisture in coal is more detrimental than ash in lowering furnace temperatures, because it is not only non-combustible, but it absorbs heat when it evaporates and is superheated to the temperature of the stack gases.

Coal—Grade Divisions

In designing furnaces, etc., for a particular quality of coal, the question is likely to arise as to what is anthracite or what is bituminous. The division between the different grades is largely empirical. That given by Kent is more generally satisfactory, and is as follows:

Anthracite—All coal with less than 7.5 per cent volatile matter in combustible.

Semi-Anthracite—All coal with 7.5 per cent to 12.5 per cent volatile matter in combustible.

Semi-Bituminous—All coal with 12.5 per cent to 25 per cent volatile matter in combustible.

Bituminous—All coal with 25 per cent to 50 per cent volatile matter in combustible.

Lignite. All coal with more than 50 per cent volatile matter in combustible.

Average weight of one cubic foot:

Bituminous ....52 pounds.
Anthracite ....54 pounds.

Average weight of one bushel containing 2,500 cubic inches:

Bituminous ....75 pounds.
Anthracite ....78 pounds.

Specific gravity:

Bituminous 1.40
Anthracite 1.70

Average bulk of one ton (2,240 pounds):

Bituminous ....43 cubic feet.
Anthracite ....41.5 cubic feet.

Analyses of Coals

With Special Reference to Fuel for Use in Gas Producers

The desirable qualities of gas coal are, a high percentage of Volatile Combustible Matter, and low percentage of Moisture, Ash and Sulphur. Moisture absorbs a portion of the heat developed to vaporize it; Ash represents the non-combustible matter, and Sulphur, while it is combustible, is injurious to the furnaces and glassware.

The analyses of coals, being made of pure, clean lump coals, do not indicate the amount of slate and earthy substances mixed with them, which would increase the percentage of ash and clinker, or non-combustible matter. For this reason the general run-of-mine may be much inferior in quality to the sample analysis.

The advisability of using Slack depends upon its cost entirely and quality as compared with the cost and quality of mine-run coal. The coal that gives the best net result is cheapest; it often happens that mine-run coal at a higher price is cheaper than slack, for the reason that a larger volume and a better quality of gas is produced, which more than covers the difference in cost. Especially is this true where freight is the greater part of the cost of coal.

The analyses given on following page have been obtained from various sources, some direct from the chemists, others from the coal companies, and we have reason to believe they are correct:

Analyses of Coals—Continued

Name	Total Combustible Matter	Volatile Combustible Matter	Fixed Carbon	Moisture	Ash	Sulphur
Pennsylvania Coals:						
Monongahela River (x)	88.69	36.75	51.93	....	7.07	....
Westmoreland, Pa.....	94.00	36.00	58.00	....	6.00	1.50
Youghiogheny River (x)	95.23	39.54	55.69	.20	4.05	.52
Indiana Coals:						
No. 1	84.46	40.25	44.21	7.57	7.97	4.01
" 2	83.85	36.45	47.40	12.73	3.42	.55
" 3	82.27	38.82	43.45	8.63	9.05	2.57
" 4	82.63	42.23	40.40	5.89	11.48	5.88
" 5	85.27	36.11	49.16	11.20	3.53	.62
" 6 (x)	93.50	37.00	56.50	2.50	4.00	....
" 7	90.00	41.00	49.00	2.50	7.50	....
" 8	92.00	44.50	47.50	4.50	3.50	....
" 9	88.00	44.00	44.00	3.50	8.50	....
" 10 (x)	95.88	38.62	57.26	2.52	1.50	.46
" 11	88.36	43.07	45.29	6.47	1.85	3.32
" 12	84.55	39.47	45.08	13.40	1.55	1.36
Kentucky Coals:						
Mined near Huntington, W. Va.						
Ashland C. & I. Co. (x)	89.94	59.92	50.02	4.48	5.58	.99
Hymans Bank	87.91	35.62	52.29	5.38	4.71	....
Mulligans Bank	90.00	34.93	56.07	5.71	3.29	....
Michigan Coals:						
Saginaw Coal Co.	88.62	37.89	50.73	7.60	3.77	.99
Southern Illinois:						
Carterville Mines	85.97	24.97	61.00	7.99	5.48	.56
Mission Field (x).....	82.65	44.50	38.15	4.37	10.38	2.60
Glen Carbon No. 2....	80.02	36.84	43.18	3.86	12.22	3.90
West Virginia Coals:						
Kanawha River, Black Brand (x)......	96.07	38.59	57.48	2.24	1.70	.22
Keystone	94.73	35.41	59.32	1.19	4.08	.967
Montana (x)..........	93.35	36.78	56.57	1.42	4.52	.71
Despard..............	93.30	40.00	53.30	....	6.70	....
Monongah............	95.69	37.08	58.61	1.24	3.08	.487
Ohio Coals:						
Forsythe Mine, Guernsey Co.	86.62	32.54	54.08	1.02	7.35	5 01
Imperial Mine (Guernsey)	91.10	34.78	56.32	3.97	4.93	.79
Hocking Valley Average..............	94.04	38.00	56.04	5.62	5.96	.98
Hocking Valley Phosphorous..........	.015—B. T. U. 12761					

Samples marked (x) we consider the best from each district for use in fuel gas producers.

Oil

Petroleum is practically the only oil which is sufficiently abundant and cheap to be used as fuel in furnaces. It possesses many advantages over solid fuels. There are three kinds of petroleum in use, namely those which on distillation yield: (1) paraffin; (2) asphalt; (3) olefin.

To the first group belong the oils of the Appalachian Range and Middle West. They are dark brown with greenish tinge. Upon distillation they yield such a variety of light oils that their value is too great to permit their general use as fuels.

To the second group belong the oils from Texas and California. These vary from reddish brown to jet black, and are used mostly for fuel.

The third group comprises oils from Russia, which are also used more extensively for fuel than for any other purpose.

In general, fuel oils consist mostly of hydrogen and carbon, but contain small percentages of sulphur, nitrogen, arsenic, phosphorous and silt. They also contain water varying from less than one per cent up to 50 per cent, depending upon the care that has been taken to remove the water which accompanies the oil when pumped from the well. Here, as in all other fuels, the percentage of water effects the available heat of the oil, hence contracts for purchase of oil should limit the content of water, else sufficient tankage should be provided to enable most of the water to be settled out of the oil before it is burned.

The specific gravity (Foster) of petroleum ranges from .628 to .792.

The boiling point ranges from 80° to 495° F. The total heating power ranges from 26,975 to 28,087 units of heat, equivalent to the evaporation, at 212° of from 24.17 to 25.17 pounds of water supplied at 62° or from 27.92 to 29.08 pounds of water supplied at 212°.

Petroleum possesses the following advantages over coal:

(1) Much lower cost for handling, as the oil is fed by simple, mechanical means, the cost of stoking, removing ashes, etc., is eliminated.

(2) For equal heat value oil occupies less space than coal, and the storage space may be at considerable distance from the furnace without detriment.

(3) Can be burned with less waste than coal. In practice, a barrel of crude petroleum (42 gallons), weighing 319 pounds, is equal to 478 pounds of good coal.

(4) Intensity of fire can be almost instantly regulated to conform to the demands made by the conditions of the furnace and its contents.

(5) Oil does not, like coal, deteriorate with age when stored.

(6) Reduction in working force, and freedom from dust, dirt and smoke, thereby permitting the production of a better grade of glass.

The disadvantages of oil are:

(1) It must have a high flash point to minimize danger of explosions.

(2) City or town ordinances may impose oppressive conditions regarding location and isolation of oil tanks.

(3) The natural supply of oil falls so far short of the demand that it can only be obtained with difficulty; consequently it cannot come into general use.

The character of fuel oil in various parts of the country varies with the question of supply and demand in a particular community, and the

nearest shipping point of oil best suited for the purposes. That is, in cases where the use of fuel oil is imperative and crude oil cannot readily be obtained, it is customary to supply a better grade of oil than is necessary, in order to meet the emergency.

Theoretically a pound of oil is equivalent in heat units to two pounds of coal, but in practice the thermal equivalent of one pound of oil is one and one-half pounds of coal.

Oil is marketed on the gallon basis; shipment being made in barrels and tank cars.

Weight and Volume of Crude Petroleums

Pound	U. S. Liquid Gallon	Barrel	Gross Ton
1.	.13158	.0031328	.0004464
7.6	1.	.02381	.003393
319.2	42.	1.	.1425
2240.	294.72	7.017	1.

Gas

In the field of glass manufacture both natural and producer gas are used for melting and heating purposes.

Natural gas is pumped from wells to the point where it is to be used, a pressure reducing station interposed between source and consumer.

The weight of natural gas is about 45.6 pounds per 1,000 cubic feet under standard conditions. The composition varies considerably, even in the same field.

Owing to the greater thermal efficiency obtained in the burning of natural gas as compared with coal, about 20,000 cubic feet of natural gas is, in practice, equivalent to 2,000 pounds of coal.

Natural Gas at six cents per thousand cubic feet will be equal in heating value to coal which evaporates seven pounds of water per pound and costs $1.12 per ton.

Producer Gas is gradually replacing natural gas in the glass manufacturing field.

To the interested reader we submit the following excellent article on the subject of commercial gas:

Commercial Gases for Fuel and Power Purposes

(Read Before Engineers' Society of Western Pennsylvania)

A Few Words Concerning Gas

By Alexander M. Gow

THE following pages are for the general information of those users of gas who desire to obtain a speaking acquaintance with the subject. Technical refinements have been avoided. Values are given in round numbers, easy to remember, not always scientifically accurate, but sufficiently so for purposes of ordinary calculations.

For further information the reader is referred to the extensive literature on the subject; this is but the alphabet.

The Constituents of Commercial Gases

By the term "gas," as used commercially, a mixture of various gases is generally understood. The relative proportions in which these constituent gases appear in a commercial gas depend upon the method of manufacture and the raw materials used. The methods of manufacture are many. The raw materials consist of air, water, and any carbonaceous matter, such as coal, coke, wood, oil or garbage. Given these raw materials, various commercial gases can be produced which differ from each other in the proportions of their constituent gases. These constituent gases are as follows: Hydrogen, oxygen, nitrogen, carbonic oxide, carbonic acid, marsh gas and olefiant gas. Sulphur also appears in small quantities and is an objectionable impurity. For the sake of brevity and convenience, certain symbols have been adopted to designate these gases. The symbol of a chemical combination tells at a glance the proportions of the different elements that have united to form it. A knowledge of the atomic and molecular weights of the elements make it a simple matter of arithmetic to calculate how many pounds of each element are in a given weight of the combination. For instance, the symbol for carbonic acid is CO_2. This shows that one atom of carbon (symbol C) has united with one molecule of oxygen (symbol O_2), to form one molecule of carbonic acid (CO_2). The atomic weight of carbon is twelve and the molecular weight of oxygen is 32. Using the symbols in the form of an equation:

$$C + O_2 = CO_2, \text{ or in pounds}$$
$$12 + 32 = 44$$

That is to say, 12 pounds of carbon unite with 32 pounds of oxygen and form 44 pounds of carbonic acid. Or, dividing through by 12, one pound of carbon unites with two and two-thirds pounds of oxygen to produce three and two-thirds pounds of carbonic acid. The symbol of olefiant gas is C_2H_4. Two atoms of carbon have united with four atoms (or two molecules) of hydrogen. Expressing this in symbols:

$$2\,C + 2\,H_2 = C_2H_4, \text{ or in pounds}$$
$$24 + 4 = 28$$

showing that 28 pounds of olefiant gas contain 24 pounds of carbon and 4 pounds of hydrogen. With this explanation of the use of symbols, let us consider the characteristics of the various gases, which, mixed together, go to make up a manufactured gas.

Hydrogen: Atomic symbol, H. Atomic weight, I. Molecular symbol, H. Molecular weight, 2. Hydrogen is so light that it has been adopted as the standard by which to weigh all other elements. When the atomic weight of hydrogen is given as 1, and that of oxygen as 16, it means that for equal volumes at the same temperatures and pressure, oxygen is 16 times as heavy as hydrogen. In the case of both oxygen and hydrogen two atoms of each combine to form one molecule of each, but the ratio of weights remains the same, 16 to 1. Hydrogen uniting with oxygen burns with a blue flame, producing water in the form of water vapor. The formula for this reaction is:

$$H_2 + O = H_2O, \text{ or in pounds}$$
$$2 + 16 = 18$$

Two pounds of hydrogen burn with 16 pounds of oxygen to form 18 pounds of water. The formula also shows the relative volume of each gas that has entered into combination. Two cubic feet of hydrogen unite with one cubic foot of oxygen. Of course the volume of water vapor produced will depend upon its temperature, and if it be condensed to water there will be but a small quantity produced by burning two cubic feet of hydrogen with one cubic foot of oxygen. But the weight of water is of course equal to the combined weights of the gases that formed it. The heat evolved by burning one cubic foot of hydrogen with one-half a cubic foot of oxygen is sufficient to raise the temperature of 320 pounds of water one degree F. A British thermal unit is the amount of heat required to raise one pound of water one degree F. The abbreviation used is B. T. U. Consequently hydrogen has a calorific or heating value of 320 B. T. U. per cubic foot.

Now, the atmosphere, which is the source of oxygen for combustion, contains 20 cubic feet of oxygen to 80 cubic feet of nitrogen. But for purposes of combustion the oxygen cannot be separated from the nitrogen. Consequently, for each cubic foot of oxygen required, four cubic feet of nitrogen go along, or five cubic feet of air. So when two cubic feet of hydrogen are burned with one cubic foot of oxygen, five cubic feet of air must be supplied. This is the theoretical requirement; as a question of fact, to insure complete combustion in practice, it is necessary to supply more oxygen, consequently more air, than this theoretical amount. In most commercial gases hydrogen appears either as free hydrogen or combined with carbon to form what is known as "hydrocarbon." The term "hydrocarbon" covers an almost unlimited number of compounds, gaseous, vaporous, liquid and solid. In general, a "heavy hydrocarbon" contains more carbon than a "light hydrocarbon." As a rule, if a "heavy hydrocarbon" is subjected to heat, in the absence of oxygen, a "light hydrocarbon" is driven off and carbon deposited. The application of heat to a "heavy hydrocarbon," whether solid or liquid, may evolve "lighter hydrocarbons" both vapors and gases, and a residue of a solid "heavy hydro-

carbon" or pure carbon may be left behind as a final product. This process of subjecting a "heavy hydrocarbon" to heat in the absence of oxygen, to evolve "lighter hydrocarbons" is called distillation. Oil gas is made by this process from crude oil. Crude oil is a mixture of various "heavy hydrocarbons." When heat is applied "lighter hydrocarbons" in the form of gases and vapors are evolved. And, if the heat be sufficiently high, these gases and vapors may be still further broken up into free hydrogen and carbon, which latter will be deposited as free carbon or lamp black. When hydrogen (H) appears in the analysis of a commercial gas it is to be considered as a desirable constituent, owing to its calorific value and the ease with which it burns to water.

Oxygen. Atomic symbol, O. Atomic weight, 16. Molecular symbol, O_2. Molecular weight, 32. One-fifth of the volume of the air is oxygen, O. It combines with nearly all other elements and heat is evolved by the combination. It is the "supporter of combustion." In commercial gases it appears only in small quantities as free oxygen (O_2) rarely more than two or three per cent. But combined with carbon it forms a large constituent of most of them, appearing in carbonic acid, (CO_2) and in carbonic oxide (CO). When free oxygen (O_2) appears in the analysis of a gas it is not to be considered as having any heating value. To the extent that it appears just that much less oxygen will have to be supplied from the air to burn the gas.

Nitrogen. Atomic symbol, N. Atomic weight, 14. Molecular symbol, N_2. Molecular weight, 28. About 80 per cent of the volume of the atmosphere is nitrogen (N_2). It is extremely inert. In this respect it is the opposite of oxygen. Only with difficulty can it be made to combine with other elements. It is evident that when air is one of the raw materials used in gas making that the gas made must contain the inert nitrogen (N_2). When it appears in the analysis of a commercial gas it is to be considered only as a diluent, having no heating value, retarding the combustion of the other gases and reducing the calorific value of the whole.

Carbonic Acid. Symbol, CO_2. Molecular weight, 44. Also known as carbon dioxide and carbonic anhydride. When carbon and oxygen are brought together at sufficiently high temperature to start combustion they burn to carbonic acid (CO_2). Heat must be supplied to start the union, but once started, heat is liberated. The combustion of one pound of carbon to carbonic acid evolves 14,500 B. T. U. Expressed in symbols:

$C + O_2 = CO_2$

$12 + 32 = 44$, or dividing by 12

One lb. carbon + $2\frac{2}{3}$ lbs. oxygen = $3\frac{2}{3}$ lbs. CO_2 = 14,500 B. T. U.

When carbonic acid appears in the analysis of a mixed gas it is to be considered as valueless as nitrogen. It has no power to produce heat. It is burnt carbon, a dead, inert gas, acting only as a diluent and reducing the calorific value of the mixture.

Carbonic Oxide. Symbol, CO. Molecular weight, 28. Also known as carbon monoxide. As said before, when carbon and oxygen combine, carbonic acid (CO_2) is formed. But if there is an excess of carbon or what

is the same thing, an insufficiency of oxygen, then carbonic oxide (CO) is formed. Expressed in symbols:

$$C + O = CO, \text{ or in pounds}$$
$$12 + 16 = 28, \text{ or dividing by twelve}$$

one pound of carbon unites with one and one-third pounds of oxygen to form two and one-third pounds of carbonic oxide, and 4,250 B. T. U. are liberated by this union. But we saw previously that one pound of carbon burnt to carbonic acid liberates 14,500 B. T. U. By comparison then,

1 lb. carbon + 2⅔ lbs. oxygen = 3⅔ lbs. CO_2	14,500 B. T. U.
1 lb. carbon + 1⅓ lbs. oxygen = 2⅓ lbs. CO	4,250 B. T. U.
Difference in burning 1 lb. carbon to CO and CO_2	10,250 B. T. U.

It is thus evident that if one pound of carbon be burnt with an insufficient supply of oxygen and the resulting carbonic acid not burnt, over two-thirds of the heating value of the carbon is lost. This frequently happens to a greater or less extent when coal is improperly burnt under boilers with an insufficient supply of air, owing to poor draft, bad firing or improper design of boiler furnace. It is not a difficult matter to make an analysis of the gases passing up the stack to determine the percentage of carbonic acid, carbonic oxide and free oxygen. If there is any carbonic oxide it is positive evidence of a useless waste of fuel.

It has been explained that carbonic acid (CO_2) is the result of the complete combustion of carbon; whereas carbonic oxide (CO) is the result of its partial combustion. It follows therefore that carbonic oxide can be burnt to carbonic acid. In formula $CO + O = CO_2$. This union evolves heat. But if, at high temperature, carbonic acid (CO_2) is brought into contact with carbon, the reaction is reversed and one cubic foot of carbonic acid (CO_2) takes up more carbon to form two cubic feet of carbonic oxide (CO). Expressing this in formula:

$$CO_2 + C = 2\,CO$$

But this is the reverse of combustion. Consequently this reaction in place of evolving heat requires heat. It cannot take place unless heat is supplied. A reaction that evolves heat is said to be exothermic. One that absorbs heat is said to be endothermic. The combination of carbon and oxygen to form carbonic acid is therefore exothermic; while the combination of carbonic acid and carbon to form carbonic oxide is endothermic. Consequently, if carbonic acid (CO_2) be passed into a red hot body of coke the carbonic acid will be transformed into carbonic oxide (CO). Heat will be rapidly absorbed and the body of coke cooled down until a temperature of about 1,500° F. is reached, when the reaction will cease. It follows, of course, that if the carbonic oxide thus formed be again given more oxygen, it will burn to carbonic acid and the absorbed heat again liberated. In a gas producer the oxygen of the air entering the bottom of the fuel bed is first converted into carbonic acid with the liberation of much heat at high temperature. But as this hot carbonic acid passes up through the fuel bed it meets more carbon and is converted into carbonic oxide (CO). This will be discussed further under the head of producer gas. Carbonic oxide is a very poisonous gas, producing asphyxiation when inhaled. It is a desirable constituent of a commercial gas.

One cubic foot burnt with one-half cubic foot of oxygen produces one cubic foot of carbonic acid. This union evolves heat. Carbonic oxide has the same calorific value as hydrogen, 320 B. T. U. per cubic foot. Consequently in a commercial gas it may be considered as having equal value with hydrogen.

Marsh Gas. Symbol CH_4. Molecular weight, 16. Also known as methane. This gas is given off in variable quantities when bituminous coal or crude oil is subjected to heat. It is also the main constituent of natural gas and forms a large percentage of "fire damp" in coal mines. When heated in the absence of oxygen it readily breaks up into carbon and hydrogen, the carbon being deposited as lamp black or appearing as black smoke. If sufficient oxygen be present the carbon burns to carbonic acid and the hydrogen to water. If there be not sufficient oxygen present the hydrogen will burn first and some of the carbon will be deposited, while the gas will burn with a smoky flame. The peculiar pungent odor so often noticeable when natural gas is used for heating is due to the incomplete combustion of marsh gas. The remedy in such cases is to supply more air or so arrange the burner that a more intimate mixture of air and gas shall be obtained. Marsh gas has a very high calorific value, the combustion of one cubic foot evolving 1,000 B. T. U., or more than three times as much as the same volume of hydrogen or carbonic oxide. Consequently it is a desirable constituent of a commercial gas. It does not burn as rapidly as hydrogen or carbonic oxide because before it can be burnt it must be broken up into its constituent carbon and hydrogen. This fact makes it a particularly desirable constituent of a gas for use in gas engines. Its presence retards the combustion of the entire mixture and lessens the liability to pre-ignition and back firing.

To burn one cubic foot of marsh gas there are required two cubic feet of oxygen, as will be seen by the formula:

$$CH_4 + 2\,O_2 = CO_2 + 2\,H_2\,O$$

But as air is one-fifth oxygen, 10 cubic feet of air are required. In practice it is always necessary to supply more than the theoretical quantity of air to insure complete combustion. Practice has shown that at least 12 cubic feet of air should be supplied for each foot of gas and in many cases this amount should be in flame, but its luminosity is not sufficient to warrant its distribution as an illuminating gas.

Olefiant Gas. Symbol $C_2\,H_4$. Molecular weight, 28. Also known as ethylene. This gas, like marsh gas, is evolved when bituminous coal or oil is subjected to heat. It burns with an intensely luminous flame. If the luminosity of marsh gas be taken as 5 candle power the luminosity of olefiant gas is 70 candle power. Consequently a mixture of gases that burn with a blue or slightly luminous flame can be rendered luminous by the addition of a few per cent of olefiant gas. It has a calorific value of 1,600 B. T. U. or five times that of hydrogen. Like marsh gas, it burns to carbonic acid and water, but as it contains more carbon than does marsh gas, more oxygen is required to burn it. One cubic foot of olefiant gas, burnt with three cubic feet of oxygen, produces water vapor and two cubic feet of carbonic acid.

By formula:

$$C_2H_4 + 3\,O_2 = 2\,CO_2 + 2\,H_2O, \text{ or by weight}$$
$$28 + 96 = 88 + 36$$

That is to say, 28 pounds of olefiant gas uniting with 96 pounds of oxygen produce 88 pounds of carbonic acid and 36 pounds of water. Of course, it is to be understood, that the products of combustion in addition to the carbonic acid and water vapor formed, must contain four cubic feet of nitrogen for every cubic foot of oxygen supplied. In the analysis of a commercial gas olefiant gas appears only in small quantities, rarely more than six per cent. On this account it cuts but little figure in a gas used for power purposes, but it is an essential in a mixed gas distributed as an illuminating gas.

Illuminants. Frequently in the analysis of a mixed gas there is specified a certain percentage of "illuminants." Generally olefiant gas is included in the "illuminants." As generally used, the term is applied to those gases and vapors that render the gas flame luminous. It frequently happens that "illuminants" are not gases at all, but vapors which will condense to liquid form at a sufficiently low temperature. They form but a small percentage of the volume of any commercial gas.

As said before, commercial gases differ from each other in the relative proportions of the constituent gases. The names given to these different mixed gases are derived from the method of manufacture and the raw materials used. We will consider the method of manufacture and the characteristics of the following commercial gases:

Bench Gas: Made by heating coal in retorts set in "benches."

Water Gas: Made by decomposing water in the presence of carbon.

Producer Gas: Made in a "producer" from air, steam and carbon.

Oil Gas: Made by subjecting oil to heat.

Carbureted Water Gas: Made by the addition of oil gas to water gas.

Coke Oven Gas: Made by heating coal in a "by-products" coke oven.

Blast Furnace Gas: Made in a blast furnace during the operation of smelting iron ore to pig iron.

Natural Gas: Made by nature, operating under a secret process.

The name "illuminating gas" does not signify the method of manufacture or the raw materials used. Both bench gas and carbureted water gas are distributed as "illuminating gas."

The name "distilled gas" is applicable to bench gas, coke oven gas and oil gas. The name "coal gas" was originally applied to bench gas exclusively, but as bench gas, producer gas and coke oven gas are all directly derived from coal, the name has lost its original significance.

Bench Gas. When bituminous coal is heated in a closed retort the volatile constituents are driven off in the form of gases and vapors. After a sufficient length of time there remains in the retort a body of coke. Before the gases thus evolved can be distributed for use or burned in a gas engine, the heavy vapors must be removed, for, if not, they will condense in the form of tar and cause clogging of pipes, sticking of valves and fouling of cylinders. Upon leaving the retorts the gases and vapors pass through the hydraulic main. This is simply a water seal that serves as a

valve to prevent the flow of gas back into the retort when it is open to be recharged. In the hydraulic main the gases and vapors bubble through a few inches of water and a portion of the vapors are condensed into tar. The gases and uncondensed vapors then pass to the condenser, where they are cooled. Here more of the vapors condense to tar. The gases now cool, and partially but by no means wholly freed from tarry vapors, pass to the exhauster. This is a positive blower and serves to draw the gases from the retorts, through the hydraulic main and condenser, and force them along through the scrubber, the purifier and into the holder ready for distribution. The purpose of the scrubber is to remove all the tarry vapors left, together with the ammonia; for, as the gases leave the retorts, they contain a certain amount of ammonia, which is in addition to being an objectionable impurity on the gas volume, is well worth saving as a by-product. Various types of scrubbers are in use, but the principle involved is to bring the gases into contact with wet surfaces and cause an intermingling of water and the gases. The tar sticks to the surfaces and the water absorbs the ammonia. From the scrubber, the gases, now freed from tarry vapors and ammonia, pass to the purifier, where carbonic acid and sulphur compounds are removed. The carbonic acid is objectionable because it seriously reduces the illuminating power of the gas and has not a heating value. Sulphur compounds are objectionable because of the offensive odor when the gas is burned. Lime and iron oxide are the materials mainly used for the purification of gas. For a full discussion of purification and the chemical reactions involved, together with a description of the various scrubbers and other apparatus, the reader is referred to the many works on the subject.

The volatile constituents of the coal first driven off from a freshly charged retort are quite different from those evolved during the last stages of the distillation process. But inasmuch as several retorts are set in one "bench" and charged successively, the gas that goes to the holder has a uniform composition. This composition will depend very largely upon the coal used and the temperature of the retorts.

The following may be taken as a typical analysis of bench gas made from a good grade of gas coal; composition by volume:

Hydrogen	H_2	46.00%	Combustible 97.00%
Marsh Gas	CH_4	40.00%	
Carbonic Oxide	CO	6.00%	
Olefiant Gas	C_2H_4	5.00%	
Carbonic Acid	CO_2	.5 %	Incombustible 3.00%
Nitrogen	N_2	2.00%	
Oxygen	O_2	.5 %	
		100.00%	

Using the calorific values before given for the constituent gases, above mixture has a calorific value of 668 B. T. U. per cubic foot. For combustion there are required 1.21 cubic feet of oxygen or 6.05 cubic feet of air, per cubic foot of gas. In practice, however, at least eight cubic feet of air should be supplied to insure complete combustion. Less than this amount will cause the gas to burn with a smoky flame and there will be more or less carbon deposited as lamp black. The products of combustion are of course water vapor, carbonic acid and nitrogen. The exact composition of gas distributed for illuminating purposes is governed by all sorts of legislation aimed at prescribing the permissible amounts of carbonic acid, carbonic oxide, sulphur and "illuminants."

Bench gas gives very satisfactory results when used in gas engines. Originally, all gas distributed was made by this retort process. But about the year of 1880 the water gas process came into use and today the general practice of illuminating gas companies is to distribute a mixture of bench gas, water gas and oil gas; water gas and oil gas together being designated carbureted water gas.

Water Gas. When steam and carbon are brought into intimate contact at high temperature the steam is decomposed into oxygen and hydrogen; the oxygen thus liberated combines with the carbon to form carbonic acid and carbonic oxide, while the hydrogen remains free. The relative amounts of carbonic acid and carbonic oxide formed will depend upon various conditions, but it is evident that the most desirable conditions are those that favor the largest production of carbonic oxide and the smallest of carbonic acid. If a body of coke, in a suitable vessel called a "producer" be blown by a blast of air until white hot, and then the blast shut off and the steam turned on, water gas will be formed. The body of coke will be rapidly cooled, for heat is absorbed by the breaking up of the steam into oxygen and hydrogen. Inasmuch as the union of oxygen and hydrogen to form water evolves heat, it follows that the conversion of water into oxygen and hydrogen must absorb heat. Consequently the formation of water by the union of oxygen and hydrogen is said to be exothermic. It evolves heat, and the opposite reaction is endothermic. It absorbs heat. And the amount of heat evolved must be equal to the amount of heat absorbed. But, as stated before, when steam is broken up in the water gas process, the liberated oxygen combines with the carbon. But this union evolves heat; that is to say, it is exothermic. But more heat is absorbed by the breaking up of the steam than is evolved by the union of its oxygen with carbon. Consequently the thermal result of the two reactions will be endothermic; the body of coke will thereby be cooled down. It becomes necessary, therefore, to store some more heat in the body of coke. This is done by shutting off the steam and blowing the coke body with air, preparatory to another steaming.

These successive "blowings" and "steamings" constitute the "intermittent water gas" process. Usually in practice two producers are used, one being blown hot while the other is steaming. A suitable arrangement of valves is provided, so that the water gas made while steaming shall be kept separate from the gases thrown off while blowing hot with air. Almost numberless modifications of these fundamental ideas have been made. The coke, except what appears in the ash as clinker, is wholly converted into gas. Theoretically pure water gas would consist of half carbonic oxide and half hydrogen and have a calorific value of 320 B. T. U. per cubic foot. But theoretical conditions are not obtained in practice and a typical analysis of water gas made from bench gas coke is as follows; composition by volume:

Hydrogen	H_2	48.00%	Combustible 88.00%
Marsh Gas	CH_4	2.00%	
Carbonic Oxide	CO	38.00%	
Carbonic Acid	CO_2	6.00%	Incombustible 12.00%
Nitrogen	N_2	5.50%	
Oxygen	O_2	.50%	
		100.00%	

Using the calorific values before given for the constituent gases, the above gas contains 295 B. T. U. per cubic foot. It will be noticed that it contains no olefiant gas (C_2H_4) nor "illuminants," consequently it burns

with a blue flame. In fact, sometimes water gas is designated "blue gas." As compared to bench gas, it is low in marsh gas (CH_4) and high in carbonic oxide (CO). Had it been made from pure carbon, it would contain no marsh gas at all. What little it does contain shows that the bench gas coke from which it was derived has not been completely coked. The large percentage of carbonic oxide (CO) makes it very poisonous, and for a time there was a very great prejudice against its use. But that prejudice has been largely overcome. It is not well adapted for use in gas engines, as it burns so rapidly and is so "snappy" that troubles arise from back-firing and pre-ignition. Inasmuch as it is made from coke and steam, it contains no tar or heavy vapors and consequently little scrubbing is required to render it clean enough for distribution. To change its flame from blue to a luminous one, there may be added to it from five to ten per cent of "illuminants." This is done by the use of oil, naphtha, "tar oil" or some similar heavy hydrocarbon which, when heated, will evolve illuminating gases and vapors. Many different arrangements are in use to accomplish this end. The resulting mixture is known as carbureted water gas. Over half the illuminating gas sold in the United States is carbureted water gas. So that a modern plant for the manufacture of illuminating gas may consist of the benches of retorts for the distilling of bench gas from coal; gas producers in which water gas is made from the coke derived from the retorts and carburetting apparatus for the enriching of the water gas with oil gas. As explained, it is necessary in the operation of a water gas producer to periodically stop steaming and blow hot. The gases passing off during the heating blow consist of the nitrogen of the air, carbonic acid and carbonic oxide, with some free oxygen. This lean gas mixture may be used to a greater or less extent to raise the steam for the steaming operation. Or it may be used to furnish the heat necessary to volatilize the oil for enriching. Naturally the water gas process lends itself to an almost infinite number of modifications. Some blow *up* through the fuel; some blow *down*; some steam upward; some steam down; some blow to produce the highest percentage of carbonic acid in the "lean" blow gases; some blow to produce the lowest percentage of carbonic acid and the highest percentage of carbonic oxide, in order that these lean, blow gases may be burned to advantage under boilers or in regenerative chambers.

Others operate so as to produce a mixture of the water gas and the best of the blow gas. It is out of place here to discuss the relative merits of these different methods of operation. Suffice it to say that by the water gas process COKE may be converted into water gas and the gas from the blow; the water gas may or may not be enriched with oil gas to increase its luminosity; the gas produced by the blow may be used in various ways.

The question arises here: Why cannot bituminous coal be used direct in the water gas producer in place of coke? It can be. Many experiments have been made to this end and many plants built for this purpose. But the losses and difficulties attendant upon the use of soft coal direct in water gas producers have prevented the general introduction of such processes. A continuous process, whereby the volatile constituents of a body of coal may be distilled, and simultaneously the resulting coke converted into water gas, producing what would be practically a mixture of bench gas and water gas, has not as yet been evolved.

Producer Gas. Of all the commercial gases producer gas is the easiest and cheapest to make. It is made by simply passing air or air and steam through a body of fuel. The fuel may be soft coal, hard coal, coke or wood. The oxygen of the air unites with the carbon to form carbonic acid and carbonic oxide. In order that the resultant gas may contain as little carbonic acid as possible, a comparatively deep bed of fuel is carried and the steam and air are caused to travel through at a moderate rate of speed. If no steam is used the fuel bed will get hotter and hotter, causing the ash to fuse to clinker and give trouble in cleaning out. Steam serves to keep the producer in good working condition, but in addition some of the steam is decomposed, so that the resulting gas will contain some carbonic acid and carbonic oxide derived from the steam oxygen and some hydrogen derived from the steam. Of course, if coke is the fuel used, there will be practically no hydrogen in the made gas except that derived from the decomposition of steam. When gasifying fuel in a gas producer and using only air as blast, the temperature becomes excessively high. There is more heat evolved by the burning of carbon to carbonic oxide than the made gases can carry away by their "sensible" heat. Then, in order to utilize this excess of heat and also to keep the producer in good working condition, steam is admitted with the air blast in such proportions as will accomplish these ends. Decomposition of a portion of the steam absorbs a portion of this excess heat. The hydrogen of this decomposition is directly added to the volume of the gas as free hydrogen. The oxygen so derived will react with carbon to form carbonic oxide and thus increase the volume of gas made. And to the extent that the steam furnishes oxygen, just so much less air-oxygen will be required and the dilution of the gas by air-nitrogen will be correspondingly lessened. When gasifying hard coal or coke, more steam can be decomposed than when gasifying soft coal, for the reason that, in the latter case the driving off and breaking up of some of the contained hydrocarbons absorbs some of the excess heat, leaving less to be used for the decomposition of steam than in the case of hard coal or coke, which contain no hydrocarbons to be distilled.

The manufacture of producer gas is a continuous one. Fuel is fed as needed and a continual supply of air and steam is added. If hard coal or coke is the fuel, the gas comes off comparatively clean and requires little scrubbing for use in gas engines. But if soft coal is used, the gas contains a large amount of tarry vapors and is extremely dirty. By suitable scrubbing it may be cleaned, when it is admirably adapted for use in gas engines. Producer gas is almost universally used in open hearth steel furnaces and regenerative heating furnaces. For such cases no scrubbing is necessary, as the flues through which the gas passes are made very large and accessible for cleaning out or burning out. When the gases reach the furnace where it is consumed, the tarry vapors are more a help than a hindrance. This gas does not burn freely when cold, consequently either the gas or the air to burn it, or preferably both, should be heated before entering the furnace. This is accomplished by passing

Typical Analyses

	H_2	CH_4	CO	C_2H_4 Illuminants	CO_2	N_2	O_2	B. T. U. Cubic Feet	O_2 for Combustion	Air for Combustion	B.T.U. in 1 Cubic Foot Explosive Mixture
Bench Gas	46.00	40.00	6.00	5.00	.50	2.00	.5	646	1.21	6.05	91.7
Water Gas	48.00	2.00	38.00	......	6.00	5.50	.5	295	.47	2.35	88.0
Prod'r Gas, Hard Coal	20.00	......	25.00	......	5.00	49.50	.5	144	.225	1.12	68.0
Prod'r Gas, Soft Coal	10.00	3.00	23.00	.50	5.00	58.00	.5	144	.24	1.20	65.5
Producer Gas, Coke	10.00	......	29.00	......	4.50	56.00	.5	125	.195	.98	63.0
Carburetted Water Gas	40.00	25.00	19.00	8.50	3.00	4.00	.5	575	1.05	5.25	92.0
Coke Oven Gas	50.00	36.00	6.00	4.00	1.50	2.00	.5	603	1.12	5.60	91.0
Blast Furnace Gas	1.00	......	27.50	......	11.50	60.00	....	91	.143	.72	53.0
Natural Gas, Pittsburg	3.00	92.00	......	3.00	......	2.00	....	978	1.945	9.73	91.0
Oil Gas	32.00	48.00	......	16.50	......	3.00	.5	846	1.615	8.07	93.0

Constituents of Commercial Gases

	Characteristics	Molecular Symbol	Molecular Weight	B. T. U. Per Cu. Ft.	B.T.U. in 1000 Cu. Ft. From 68°-68° F.	Cu. Ft. O_2 to Burn 1 Cubic Ft.	Products of Combustion
Hydrogen	Blue Flame, Very "Snappy"	H_2	2	320	320,900	.5	H_2O
Oxygen	Supporter of Combustion	O_2	32	......	....	......	....
Nitrogen	Inert	N_2	28	......	....	......	....
Carbonic Acid	Inert, Burnt Carbon	CO_2	44	......	....	......	....
Carbonic Oxide	Very Poisonous, Partially Burnt, C. Blue Flame	CO	28	320	320,580	.5	CO_2
Marsh Gas	Slightly Luminous, Odorless	CH_4	16	1000	993,550	.2	CO_2 & $2H_2O$
Olefiant Gas	Luminous	C_2H_4	28	1600	1,560,100	.3	$2CO_2$ & $2H_2O$
Acetylene	Very Luminous	C_2H_2	26	......	... .	2.5	$2CO_2$ & H_2O

the air and gas through chambers filled with brick which have been heated previously by the products of combustion leaving the furnace. A furnace so equipped is known as a regenerative furnace and the chambers as regenerative chambers. It is evident that two sets of such chambers are required, one set being heated by the products of combustion, while the other set are heating the air and gas passing through them. A suitable arrangement of reversing valves is provided whereby the operation of the two sets of chambers may be reversed. The fact that producer gas does not burn readily when cold, together with the fact that it contains about 60 per cent of incombustible constituents, render it unfit for general distribution. Many gas "processes" have been exploited, which consist in adding a percentage of oil gas to producer gas. Of course the heating value of the mixture will be enhanced by the amount of heat in the oil gas added. And sufficient oil gas may be mixed with producer gas to make the mixture luminous. But even with such additions the resulting mixture must contain the inert nitrogen derived from the air in the manufacture of the producer gas together with the unavoidable presence of more or less inert carbonic acid. While producer gas varies, according to the fuel used and the condition of the producer, the following may be taken as a typical analysis, using soft coal, with the producer in good condition; composition by volume:

Hydrogen	H_2	10.00%	Combustible 36.50%
Marsh Gas	CH_4	3.00%	
Olefiant Gas	C_2H_4	.50%	
Carbonic Oxide	CO	23.00%	
Carbonic Acid	CO_2	5.00%	Incombustible 63.5%
Oxygen	O_2	.5 %	
Nitrogen	N_2	58 00%	
		100.00%	

Using the calorific values given before for the constituent gases the above gas has a calorific value of 144 B. T. U. per cubic foot. It has about one-seventh the heating value of natural gas. Inasmuch as carbonic oxide (CO) burns to carbonic acid (CO_2) it is evident that the presence of carbonic acid in the analysis indicates that the producer has been operated in such a manner that some of the carbonic oxide has been burned in the producer.

A typical analysis of producer gas from hard coal is as follows:

Hydrogen	H_2	20.00%	Combustible 45.00%
Carbonic Oxide	CO	25.00%	
Carbonic Acid	CO_2	5.00%	Incombustible 55.00%
Oxygen	O_2	.5 %	
Nitrogen	N_2	49.50%	
		100.00%	

The above gas has a calorific value of 144 B. T. U. per cubic foot. But it is noticeably different from the analysis of gas derived from soft coal in the higher percentage of hydrogen and the entire absence of marsh gas. The higher percentage of hydrogen is due to the decomposition of steam, as already explained.

To make gas of the above analysis demands that the producer be handled with intelligence and kept in the best working condition.

Oil Gas. When crude oil, refined oil, tar, naphtha, "tar oil" or any of the heavy, liquid hydrocarbons are subjected to heat they are broken up to a greater or less extent and gases and vapors are evolved. The gases thus evolved are hydrogen, marsh gas and olefiant gas. The vapors are not "fixed gases," but will condense to liquid form at lower temperature. But a gas will serve as a "carrier" for a certain amount of vapor.

Just as air will carry a certain amount of water vapor, depending upon its temperature, so will any gas or mixtures of gases carry a certain amount of vapors of hydrocarbons. Thus, when gasoline is used in gas engines, it is not converted into a gas before entering the cylinder; it is only vaporized and the air serves as the carrier of the vapor. Gasoline vaporizes at ordinary atmospheric temperatures and requires no heating to induce it to give off its vapors. Ordinary kerosene vaporizes at about 150° F., and if heated to this temperature it can be used in gas engines the same as gasoline, and air can be used as the carrier to convey the vapor into the cylinder of the engine. The temperature at which an oil begins to evolve an inflammable vapor is called its "flash point." Usually this vapor can be broken up into a lower hydrocarbon by the application of more heat at higher temperatures. Such breaking up will be generally accompanied by the deposition of carbon. The most general application of oil gas is for carburetting water gas to change the blue flame to a luminous one. In round numbers a barrel of crude oil contains 7,000,000 B. T. U. A ton of good soft coal contains 28,000,000 B. T. U. So that four barrels of oil are equivalent in heating effect to one ton of coal. But it is possible to burn oil more efficiently than coal is usually burned. This is partially due to the unavoidable loss of a portion of the coal in the ash and clinker. Consequently, it has been found in practice, that about three and one-half barrels of crude oil are equal to one ton of coal, when both are burned under favorable conditions, attainable in good practice. Various oil gas processes have been exploited and all sorts of claims have been made as to the amount of gas and its calorific value that can be derived from one barrel of oil. But, in considering such processes, it is well to keep in mind that a barrel of oil contains a certain number of thermal units. To gasify the oil will require a certain number of thermal units. If there were no loss of heat in the gasification process, which is a condition unattainable in practice, then the gas made from the barrel of oil would contain just the thermal units contained in the oil originally, plus that amount required to gasify the oil. In other words, the only thermal gain that can be made by gasifying oil and burning it, over burning it direct, is that due to the more complete combustion that can be obtained when the oil has been first gasified or vaporized. As a question of fact, crude oil can be burned with properly designed burners, which insure a complete mixture of air and oil, with as high an efficiency as can be obtained by first vaporizing it and then burning it. No typical analysis of oil gas can be given, for the composition depends upon the oil from which the gas is derived and the temperature to which the oil has been subjected, but the following may be taken as typical of oil gas made from Pennsylvania crude oil; analysis by volume:

Hydrogen	H_2	32.0%	Combustible 96.5%
Marsh Gas	CH_4	48.0%	
Illuminants	C_2H_4	16.5%	
Nitrogen	N_2	3.0%	Incombustible 3.5%
Oxygen	O_2	.5%	
		100.0%	

The preceding gas is noticeably different from bench gas in the high percentage of illuminants.

Coke Oven Gas. Most of the coke used for metallurgical purposes is made in "Beehive" ovens and no attempt is made to save the volatile constituents of the coal. The product desired is coke, not gas. But of recent years there has been introduced the "by-products coke oven," in the operation of which the gases, tar and ammonia evolved by distilling the coal in closed retorts or ovens are saved as in the bench gas process. A considerable portion of the gases evolved are used in heating the ovens. The remainder is almost identical in its composition with bench gas. Generally it is higher in hydrogen and lower in "illuminants" than bench gas, because the ovens are operated to produce a hard coke suitable for metallurgical purposes and the illuminating power of the gas is a secondary consideration. For use in gas engines it may be considered as bench gas. When it leaves the ovens it is very dirty, and before it can be distributed or used in engines, must be thoroughly scrubbed. Inasmuch as the scrubbing process recovers valuable by-products in the form of ammonia and tar, it more than pays for itself.

Blast Furnace Gas. The gas evolved from a blast furnace during the operation of smelting iron ore to pig iron is very similar to a low grade or lean producer gas. Notwithstanding its very low calorific value, rarely over 100 B. T. U. per cubic foot, it gives excellent results when used in gas engines. Bell, in "Iron and Steel," gives the following as an average analysis:

Hydrogen	H_2	.70%	Combustible 27.40%
Carbonic Oxide	CO	26.70%	
Carbonic Acid	CO_2	11.70%	Incombustible 72.60%
Nitrogen	N_2	60.90%	
		100.00%	

The above gas has a calorific value of 88 B. T. U. per cubic foot. Upon leaving the furnace the gas contains considerable fine dust, particles of the furnace charge, which may be readily removed by suitable scrubbing apparatus. As coke is the fuel in the blast furnace, almost invariably, the gas contains no tar or heavy vapors. There can be no doubt that the next few years will show a great development of the use of this gas for purposes of power.

Natural Gas. Natural gas varies considerably in its composition. But its chief constituent is always marsh gas. This may vary from 85 to 93 per cent of the total volume. Sometimes considerable hydrogen is present, indicating that some marsh gas has been broken up by heat. Also it not infrequently carries a small percentage of oil vapors. Its calorific value is usually about 1,000 B. T. U. per cubic foot. It works admirably in gas engines. Particular care must always be taken to insure sufficient air for combustion. About 14 cubic feet of air should be supplied for each cubic foot of gas. When an insufficient supply of air is given there will result a deposit of carbon and the formation of a small percentage of acetylene, C_2H_2 giving a pungent odor to the products of combustion.

Multipliers to be Used for Gas Measured at Pressures Greater than Four Ounces

Atmospheric Pressure 14.7 lbs. per square inch.

Temperature 60 Fahrenheit. Barometer 30 inches

Compiled by T. B. Wylie for Equitable Meter Company

Pres. in lbs.	Multiplier	Pres. in lbs.	Multiplier	Pres. in lbs.	Multiplier	Pres. in lbs.	Multiplier	Pres. in lbs.	Multiplier	Pres. in lbs.	Multiplier
½	1.0167	17½	2.1538	34½	3.2910	51½	4.4281	68½	5.5652	85½	6.7023
1	1.0502	18	2.1871	35	3.3244	52	4.4615	69	5.5987	86	6.7358
1½	1.0836	18½	2.2207	35½	3.3579	52½	4.4950	69½	5.6321	86½	6.7692
2	1.1171	19	2.2542	36	3.3913	53	4.5284	70	5.6656	87	6.8027
2½	1.1505	19½	2.2876	36½	3.4247	53½	4.5619	70½	5.6990	87½	6.8361
3	1.1839	20	2.3211	37	3.4582	54	4.5953	71	5.7324	88	6.8696
3½	1.2174	20½	2.3545	37½	3.4916	54½	4.6288	71½	5.7659	88½	6.9030
4	1.2508	21	2.3880	38	3.5251	55	4.6622	72	5.7993	89	6.9365
4½	1.2843	21½	2.4214	38½	3.5585	55½	4.6957	72½	5.8328	89½	6.9699
5	1.3177	22	2.4548	39	3.5920	56	4.7291	73	5.8662	90	7.0033
5½	1.3512	22½	2.4883	39½	3.6254	56½	4.7625	73½	5.8997	90½	7.0368
6	1.3846	23	2.5217	40	3.6589	57	4.7960	74	5.9331	91	7.0702
6½	1.4181	23½	2.5552	40½	3.6923	57½	4.8294	74½	5.9666	91½	7.1037
7	1.4515	24	2.5886	41	3.7258	58	4.8629	75	6.	92	7.1371
7½	1.4849	24½	2.6221	41½	3.7592	58½	4.8963	75½	6.0334	92½	7.1706
8	1.5184	25	2.6555	42	3.7926	59	4.9298	76	6.0669	93	7.2040
8½	1.5518	25½	2.6890	42½	3.8261	59½	4.9632	76½	6.1003	93½	7.2375
9	1.5853	26	2.7224	43	3.8595	60	4.9967	77	6.1338	94	7.2709
9½	1.6187	26½	2.7559	43½	3.8930	60½	5.0301	77½	6.1672	94½	7.3043
10	1.6522	27	2.7893	44	3.9264	61	5.0635	78	6.2007	95	7.3378
10½	1.6856	27½	2.8227	44½	3.9599	61½	5.0970	78½	6.2341	95½	7.3712
11	1.7191	28	2.8562	45	3.9933	62	5.1304	79	6.2676	96	7.4047
11½	1.7525	28½	2.8896	45½	4.0268	62½	5.1639	79½	6.3010	96½	7.4381
12	1.7860	29	2.9231	46	4.0602	63	5.1973	80	6.3344	97	7.4716
12½	1.8194	29½	2.9565	46½	4.0936	63½	5.2308	80½	6.3679	97½	7.5050
13	1.8528	30	2.9900	47	4.1271	64	5.2642	81	6.4013	98	7.5385
13½	1.8863	30½	3.0234	47½	4.1605	64½	5.2977	81½	6.4348	98½	7.5719
14	1.9197	31	3.0569	48	4.1940	65	5.3311	82	6.4682	99	7.6053
14½	1.9532	31½	3.0903	48½	4.2274	65½	5.3645	82½	6.5017	99½	7.6388
15	1.9866	32	3.1237	49	4.2609	66	5.3980	83	6.5351	100	7.6722
15½	2.0201	32½	3.1572	49½	4.2943	66½	5.4314	83½	6.5686		
16	2.0535	33	3.1906	50	4.3278	67	5.4649	84	6.6020		
16½	2.0870	33½	3.2241	50½	4.3612	67½	5.4983	84½	6.6355		
17	2.1204	34	3.2575	51	4.3946	68	5.5318	85	6.6689		

Multipliers to be used to correct above table when volume at pressure other than four ounces is desired.

Pressure	Multiplier	Pressure	Multiplier
6 oz.	.99171	2 pound	.89521
8 oz.	.98355	3 "	.84463
10 oz.	.97553	4 "	.79946
12 oz.	.96764	5 "	.75888
1 pound	.95223		

Example: The multiplier on table for 75 lbs. is 6.0000.

This multiplied by .97553 is 5.85318, the multiplier to be used for 75 lbs. to find the volume at 10 ounces.

Miscellaneous

Specific Gravity

THE specific gravity of a body is the ratio between its weight and the weight of a like volume of distilled water at a temperature of 39.2° F. For aeriform bodies, air is taken as the unit.

Names of Substances

Metals	Specific Gravity	Weight Per Cu. Inch Lbs.
Platinum, rolled	22.669	.798
" wire	21.042	.761
" hammered	20.337	.736
Gold, hammered	19.361	.700
" pure cast	19.258	.697
" 22 carats fine	17.486	.733
Mercury, solid at 40° F.	15.632	.566
" at 1-32° F.	13.619	.493
" at 60° F.	13.580	.491
" at 212° F.	13.375	.484
Lead, pure	11.330	.410
" hammered	11.388	.412
Silver, hammered	10.511	.381
" pure	10.474	.379
Bismuth	9.823	.355
Copper, wire and rolled	8.878	.321
" pure	8.788	.318
Bronze, gun metal	8.700	.315
Brass, common	7.820	.282
Steel, cast steel	7.919	.286
" common soft	7.833	:283
" hardened and tempered	7.818	.283
Iron, pure	7.768	.281
" wrought and rolled	7.780	.282
" hammered	7.789	.282
" cast	7.207	.261
Tin, from Bohem	7.312	.265
" English	7.291	.264
Zinc, rolled	7.191	.260
Antimony	6.712	.244
Aluminum	2.500	.090
Stones and Earths		
Emery	4.000	.144
Limestone	2.700	.097
Asbestos, starry	3.073	.1110
Glass, flint	2.933	.1060
" white	2.892	.1040
" bottle	2.732	.0987
" green	2.642	.0954
Marble, Parian	2.838	.1030
" African	2.708	.0978
" Egyptian	2.688	.0964
Mica	2.800	.1000
Chalk	2.784	.1000
Coral, red	2.700	.0974
Granite, Susquehanna	2.704	.0976
" Quincy	2.652	.0958
" Patapsco	2.640	.0954
" Scotch	2.625	.0948

Stones and Earths—Continued	Specific Gravity	Weight Per Cu. Inch Lbs.
Marble, white Italian	2.708	.0978
" common	2.686	.0968
Talc, black	2.900	.0105
Quartz	2.660	.0962
Slate	2.672	.0965
Pearl, oriental	2.650	.0957
Shale	2.600	.0940
Flint, white	2.594	.0936
" black	2.582	.0933
Stone, common	2.520	.0910
" Bristol	2.510	.0906
" mill	2.484	.0897
" paving	2.416	.0873
Gypsum, opaque	2.168	.0783
Grindstone	2.143	.0775
Salt, common	2.130	.0770
Saltpetre	2.090	.0755
Sulphur, native	2.033	.0735
Common soil	1.984	.0717
Rotten stone	1.981	.0416
Clay	1.930	.0698
Brick	1.900	.0686
Nitre	1.900	.0686
Plaster of Paris	1.872 2.473	.0677 .0894
Ivory	1.822	.0659
Sand	2.650	.0958
Phosphorus	1.770	.0640
Borax	1.714	.0620
Coal, Anthracite	1.640	.0593
" Maryland	1.436 1.355	.0519 .0490
" Scotch	1.300	.0470
" Newcastle	1.270	.0460
" Bituminous	1.350	.0488
Earth, loose	1.500	.0542
Lime, quick	1.500	.0549
Charcoal	0.441	.0160
Woods (Dry)		
Alder	.800	.0289
Apple tree	.793	.0287
Ash, the trunk	.845	.0306
Bay tree	.822	.0297
Beech	.852	.0308
Box, French	.912	.0330
Box, Dutch	1.328	.0480
Box, Brazilian red	1.031	.0373
Cedar, wild	.596	.0219
Cedar, Palestine	.613	.0222
Cedar, American	.561	.0203
Cherry tree	.715	.0259
Cork	.240	.0087
Ebony, American	1.331	.0481
Elder tree	.695	.0252
Elm	.560	.0202
Filbert tree	.600	.0217
Fir, male	.550	.0199

Woods (Dry)—Continued	Specific Gravity	Weight Per Cu. Inch Lbs.
Fir, female	.498	.0180
Hazel	.600	.0217
Lemon tree	.703	.0254
Lignum-vitae	1.333	.0482
Linden tree	.604	.0219
Logwood	.913	.0331
Mahogany, Honduras	.560	.0202
Maple	.750	.271
Mulberry	.897	.0324
Oak	.950	.0343
Orange tree	.705	.0255
Pear tree	.661	.0239
Poplar	.383	.0138
Poplar, white Spanish	.529	.0191
Sassafras	.482	.0174
Spruce	.500	.0181
Spruce, old	.460	.0166
Pine, yellow, Southern	.72	.0260
Pine, white	.400	.0144
Walnut	.671	.0243
Liquids		
Acid, Acetic	1.062	.0384
" Nitric	1.217	.0440
" Sulphuric	1.841	.0666
" Muriatic	1.200	.0434
" Phosphoric	1.558	.0563
Alcohol, commercial	.833	.0301
" pure	.792	.0287
Beer, lager	1.034	.0374
Champagne	.997	.0360
Cider	1.018	.0361
Ether, sulphuric	.739	.0267
Egg	1.090	.0394
Honey	1.450	.0524
Human blood	1.054	.0381
Milk	1.032	.0373
Oil, linseed	.940	.0340
" olive	.915	.0331
" turpentine	.870	.0314
" whale	.932	.0337
Proof spirit	.925	.0334
Vinegar	1.080	.0390
Water, distilled	1.000	.0361
" sea	1.030	.0371
Wine	.992	.0359
Miscellaneous		
Beeswax	.965	.0349
Butter	.942	.0341
India rubber	.933	.0338
Fat	.923	.0334
Gunpowder, loose	.900	.0325
" shaken	1.000	.0361
Gum arabic	1.452	.0525
Lard	.947	.0343
Spermaceti	.943	.0341
Sugar	1.605	.0580

Miscellaneous—Continued	Specific Gravity	Weight Per Cu. Inch Lbs.
Tallow, sheep	.924	.0334
" calf	.934	.0338
" ox	.923	.0334
Atmospheric air	.0012	.....

Gases, Vapors		Weight Cu. Ft. Grains
At 32° and a tension of one atmosphere.		
Atmospheric air	1.000	527.0
Ammoniacal gas	.500	263.7
Carbonic acid	1.527	805.3
Carbonic oxide	.972	512.7
Light carbureted hydrogen	.557	293.5
Chlorine	2.500	1316.0
Hydriodic acid	4.346	2290.0
Hydrogen	.069	36.33
Oxygen	1.104	581.8
Sulphureted hydrogen	1.191	627.7
Nitrogen	.972	512.0
Vapor of alcohol	1.613	851.0
Vapor of turpentine spirits	5.013	2642.0
Vapor of water	.623	328.0
Smoke of bituminous coal	.102	53.8
Smoke of wood	.900	474.0
Steam at 212° F.	.488	257.3

The weight of a cubic foot of any solid or liquid is found by multiplying its specific gravity by 62.425 pounds avoirdupois. And the weight of a cubic foot of any gas at atmospheric pressure and at 32° F. is found by multiplying its specific gravity by .08073 pounds avoirdupois.

Specific Heat. The quantity of heat required to raise the temperature of unit weight of any substance one degree varies with the substance. It is also the ratio of the heat so required to that required to heat the same weight of water. For solids at ordinary temperatures the specific heat is constant for each individual substance, although it is variable at high temperatures. In the case of gases a distinction must be made between specific heat at constant volume and a constant pressure.

Where merely specific heat is stated it implies specific heat at ordinary temperature, and mean specific heat refers to the average value of this quantity between the temperatures named.

The specific heat of a mixture of gases is obtained by multiplying the specific heat of each constituent gas by the percentage of that gas in the mixture and dividing the sum of the products by 100.

Latent Heat. Where there is an application of heat to a body, changing it from a solid to a liquid, or a liquid to a gas, there is an absorption of heat without any rise in temperature. The heat thus absorbed is called "latent" (or hidden) because it apparently disappears and is not measurable with a thermometer. It is not lost, however, but reappears whenever the substance passes through the reverse cycle from a gaseous to a liquid or from a liquid to a solid state. Therefore, latent heat is the quantity of heat which apparently disappears or is lost to thermometer measurement when the molecular constitution of body is changed. It is expended in performing the work of overcoming the molecular cohesion

of the particles of the substance and in overcoming the resistance of external pressure to change the volume of the heated body.

If heat be applied to a pound of ice there will be a rise in temperature until the freezing point, 32° F., is reached. The ice will then begin to melt, but the temperature of the mixture of ice and water will remain the same (32° F.) as long as any particle of ice remains in it. Yet the melting process will absorb heat. The amount of heat thus absorbed in changing the state of a pound of ice from ice at 32° F. to water at 32° F. is 144 B. T. U. This is the latent heat of fusion of ice. If the application of heat be continued, the temperature of the water will rise, but it will now only require about twice as many heat units to effect a rise of one degree as it did to effect the same rise in the ice. The reason is that the specific heat of water is 1.00, while that of ice is only .504. When the water has reached a point of 212° F., there is a further absorption of heat with no increase of temperature. Boiling occurs and the heat absorbed is expended in transforming the water into steam. Water at atmospheric pressure cannot be heated above 212° F. and the steam which is formed is also at a temperature of 212° F. When the entire pound of water has been evaporated into steam 965.8 B. T. U. have been used in the operation. This is the latent heat of evaporation of water.

Effect of Heat on Various Bodies

Melting, Freezing and Boiling Points

	Degree F.
Acetate of soda saturated	225.8
Acetate of potash saturated	336.
Air furnace	3300.
Ambergris melts	145.
Ammonia boils	140.
Ammonia (liquid) freezes	46.
Antimony melts	951.
Arsenic melts	365.
Benzine melts	176.
Beeswax melts	151.
Bismuth melts	476.
Blood (human) heat	98.
Blood (human) freezes	25.
Brandy freezes	7.
Brass melts	1900.
Carbonate of soda (saturated)	220.3
Carbonic acid	107.
Chloroform	140.
Cadmium melts	600.
Charcoal burns	300.
Coal tar boils	325.
Cold, greatest, artificial	—166.
Cold, greatest, natural	—56.
Common fire	790.
Copper melts	2548.
Ether (sulphuric)	100.
Glass melts	2200.
Gold, fine, melts	2590.
Gutta percha softens	145.
Highest natural temp. Egypt	117.
Iodine	225.
Ice melts	32.

	Degree F.
Iron (cast) melts	2100.
Iron (wrought)	2980.
Iron bright red in the dark	752.
Iron red hot in the twilight	884.
Lard melts	94.
Lead melts	540.
Mercury boils	662.
Mercury volatilizes	680.
Mercury freezes	39.
Milk	30.
Milk boils	213.
Naphtha boils	186.
Nitric acid, specific gravity 1424, freezes	45.
Nitro-glycerine	45.
Nitrous oxide freezes	150.
Olive oil freezes	36.
Petroleum boils	306.
Phosphorus melts	108.
Phosphorus boils	560.
Pitch melts	91.
Platinum melts	3080.
Potassium melts	135.
Proof spirit freezes	7.
Saltpetre melts	610.
Sea water freezes	28.
Silver (fine) melts	1250.
Snow and salt, equal parts	0.
Spermaceti melts	112.
Spirits of turpentine freezes	14.
Steel melts	2500.
Steel, polished, blue	580.
Steel, polished, straw colored	460.
Strong wines freeze	20.
Sulphur melts	226.
Sulphur acid, specific gravity 1641, freezes	45.
Sulphuric ether freezes	46.
Sulphuric ether boils	98.
Tallow melts	97.
Tin melts	421.
Vinegar freezes	28.
Vinous fermentation	60. to 77.
Water boils	212.
Water in vacuum boils	98.
White oil	630.
Zinc melts	740.
Zinc boils	1872.

Live Loads for Floors

The following loads per square foot, exclusive of weight of floor materials, show the range assumed in usual practice:

Dwellings	70 lbs. per sq. ft.
Offices	70 to 100 lbs. per sq. ft.
Buildings for public assembly	120 to 150 lbs. per sq. ft.
Stores, warehouses, etc.	150 to 250 lbs. and upwards per square foot

Weight of a Cubic Foot of Miscellaneous Substances

	Lbs.
Alcohol	49
Aluminum	162
Anthracite, solid	93
Anthracite, loose	54
Ash, white, dry	38
Asphaltum	87
Brass, cast	504
Brass, rolled	524
Brick, pressed	150
Brick, common, hard	125
Brick, soft, interior	100
Brickwork, pressed	140
Brickwork, ordinary	112
Brick, fire	120
Cedar	35
Cement, hydraulic	50-56
Cement, Portland	100
Cherry, dry	42
Chestnut, dry	41
Clay, Potter's, dry	119
Clay, in lump, loose	63
Coal, bituminous, solid	84
Coal, bituminous, broken	49
Coke, loose	26.3
Copper, cast	542
Copper, rolled	548
Cork	15
Earth, loam, dry, loose	76
Earth, loam, moderately rammed	95
Earth, soft flowing mud	108
Ebony	83
Elm, dry	35
Flint	162
Glass, molten	150
Glass, window	165
Gold	1203⅔
Granite	106
Plaster of Paris	142
Hay, bale	9
Hemlock, dry	25
Hickory, dry	53
Ice	58.7
Iron, cast	450
Iron, wrought	485
Lead	711
Lime, loose	53
Limestone	168
Maple	47
Mortar	110
Marble, Italian	169
Marble, Vermont	165
Oak, live, dry	59
Oak, white, dry	50
Pine, white, dry	25
Pine, yellow, dry, Northern	35
Pine, yellow, dry, Southern	45
Platina	219
Sand, loose	90-106

Weight of a Cubic Foot of Miscellaneous Substances—Continued

	Lbs.
Sandstone	151
Silver	625⅔
Shale	162
Snow, fresh fallen	5-12
Snow, wet by rain	15-50
Steel plates	487¾
Steel, soft	489
Stone, common, about	158
Sand, wet, about	128
Spruce	31
Tin	455
Water	62⅓
Water, sea	64
Zinc	437
Green timber (more than dry)	1/5 to ½

Antidotes for Poisons

FIRST: Send for a physician.

SECOND: Induce vomiting by tickling throat with feather or finger; drinking hot water or strong mustard and water. Swallow sweet oil or whites of eggs.

Acids are antidotes for Alkalies, and vice versa.

Special Poisons and Antidotes

ACIDS: Muriatic, Oxalic, Acetic; Sulphuric (Oil of Vitriol); Nitric (Aqua Fortis) — Soap Suds; Magnesia; Limewater

Prussic Acid —Ammonia in water. Dash water in face.
Carbolic Acid—Flour and water, mucilaginous drinks.

ALKALIES: Potash, Lye, Hartshorn, Ammonia — Vinegar or lemon juice in water.

Arsenic, Rat Poison, Paris Green — Milk, raw eggs, sweet oil, limewater, flour and water.

Bug Poison, Lead, Saltpetre, Corrosive Sublimate, Sugar of Lead, Blue Vitriol — Whites of eggs or milk in large doses.

Chloroform, Chloral, Ether — Dash cold water on head and chest. Artificial respiration.

Carbonate of Soda, Copperas, Cobalt — Soap suds and mucilaginous drinks.

Iodine, Antimony, Tartar Emetic — Starch and water, astringent infusions, strong tea.

Mercury and its Salts—Whites of eggs, milk, mucilaginous drinks.

Opium, Morphine, Laudanum, Paregoric, Soothing Powders and Syrups — Strong coffee, hot bath, keep awake and moving at any cost.

Resuscitation

Persons Rescued from Asphyxia and Drowning

Extracted from "Prompt Aid to the Injured"

By Alvah H. Doty, M. D.

The treatment of persons suffering from asphyxia and drowning is in both cases identical.

Asphyxia is a condition of unconsciousness due to a great diminution of oxygen in the blood, resulting either from an obstruction to the passage of air to the lungs, or to the presence of poisonous gases which render the air unfit for respiration. Among the numerous causes of suffocation, drowning and asphyxia following the inhalation of poisonous gases are most important for present consideration.

Asphyxia

The appearance of a person suffering from asphyxia is well marked. The face is of a dusky or purplish hue and swollen. The respirations are extremely labored, and associated with convulsive movements and delirium. If relief is not promptly given, these symptoms are rapidly followed by unconsciousness and death.

Treatment—The first step consists in removing the cause in order that the lungs may be supplied with the proper amount of pure air. Stimulants and artificial respiration are then resorted to in an effort to restore the different functions to their normal condition.

Artificial Respiration—Sylvester's Method. Before artificial respiration is begun, the patient should be stripped to the waist, and the clothing around the latter part should be loosened so that the necessary manipulations of the chest may not be interfered with. The patient is to be placed on his back (Fig. 1) with a roll made of a coat or a shawl under the shoulders; the tongue should then be drawn forward and retained by a handkerchief which is placed across the extended organ and carried under the chin, then crossed and tied at the back of the neck. An elastic band or small rubber tube or a suspender may be substituted for the same purpose. If no other means can be made available, a hat or scarf pin may be thrust vertically through the end of the tongue without injury to this organ. The attendant should kneel at the head and grasp the elbows of the patient and draw them upward until the hands are carried above the

Fig. 1. Sylvester's Method. First Movement. (Inspiration)

head and kept in this position until one, two, three can be slowly counted. This movement elevates the ribs, expands the chest, and creates a vacuum in the lungs into which the air rushes, or, in other words, the movement produces *inspiration.* The elbows are then slowly carried downward, placed by the side, and pressed inward against the chest (Fig. 2), thereby diminishing the size of the latter and producing *expiration.* These movements should be repeated about fifteen times during each minute for at least two hours, provided no signs of animation present themselves.

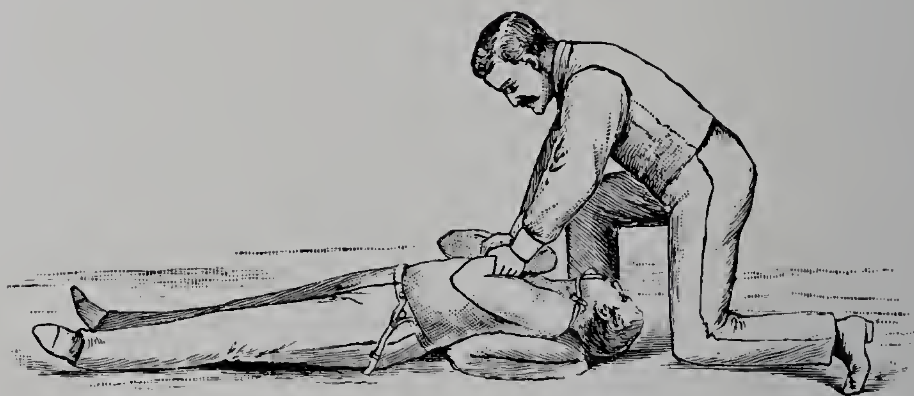


FIG. 2. Sylvester's Method. Second Movement. (Expiration)

Drowning

In the case of asphyxia or suffocation following submersion it is due to the fact that air is prevented from reaching the lungs. More or less water is found in the air passages, but not in such quantities as is generally supposed. Water, however, enters the stomach, and considerable is found mixed with mucus in the throat. Death is usually the result of suffocation. In some cases it may be due to sudden heart failure before the person sinks. When such is the case, the face of the drowned would be pale and flabby. There is a better chance of resuscitating one who sinks from this cause than when suffocated, as the demand for oxygen in the former is less than when asphyxiated by submersion.

FIG. 3. Howard's Method for Water Expulsion.

Treatment Preliminary to Artificial Respiration—The patient should be placed face downward, with a pillow or roll of clothing under the pit of the stomach, the head resting on the forearm, which keeps the mouth from the ground and renders traction on the tongue unnecessary. The attendant standing over the drowned person (Fig. 3), should then place his left hand on the lower and back part of the left side of the chest, while the right hand is laid on the spinal column about on a line or a little above the left hand; firm pressure is then made by the operator throwing the weight of his body forward on his hands; this is to be continued while one, two, three are counted (slowly) and ended with a push which helps to raise the operator to an upright position and forcibly expel the fluid. These movements should be repeated two or three times if fluid continues to flow from the mouth.

The patient should then be turned on his back and Sylvester's method of artificial respiration (Figs. 1 and 2) applied.

Smelling salts, ammonia, or two or three drops of nitrate of amyl, may be administered by inhalation, or the nose may be tickled by a feather or straw. When breathing commences and consciousness returns, the patient should be carefully divested of all wet clothing (if necessary, the clothing should be cut to avoid delay), well rubbed, and wrapped in warm covering, and stimulants administered.

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